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CONTENTS

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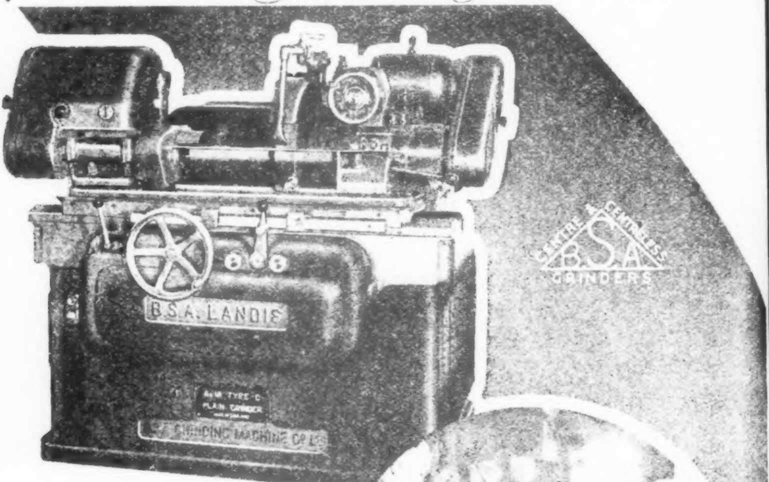

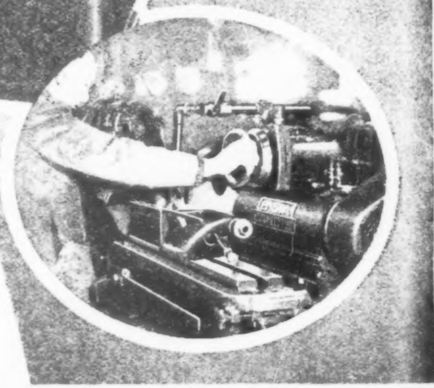

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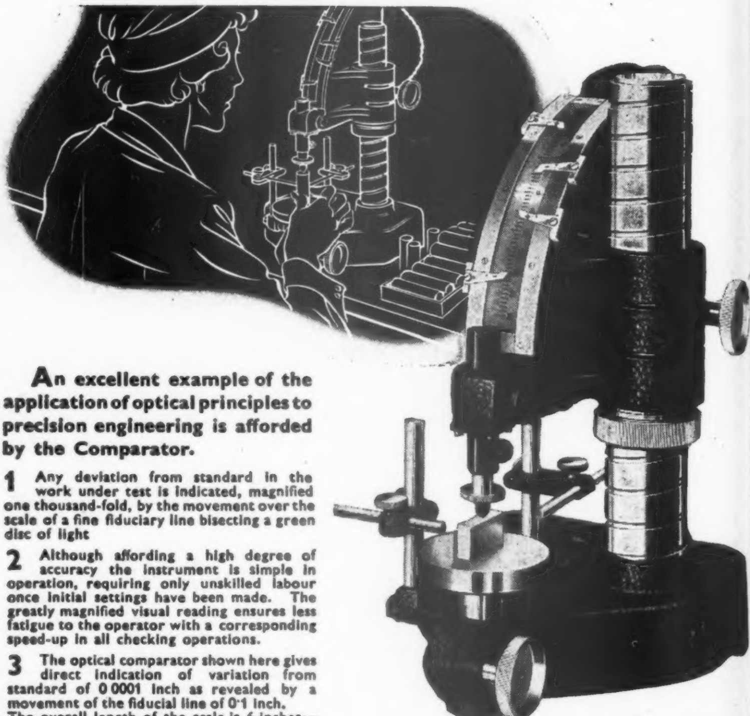

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Leaflet No. 838 B describes the Comparator and accessories in detail

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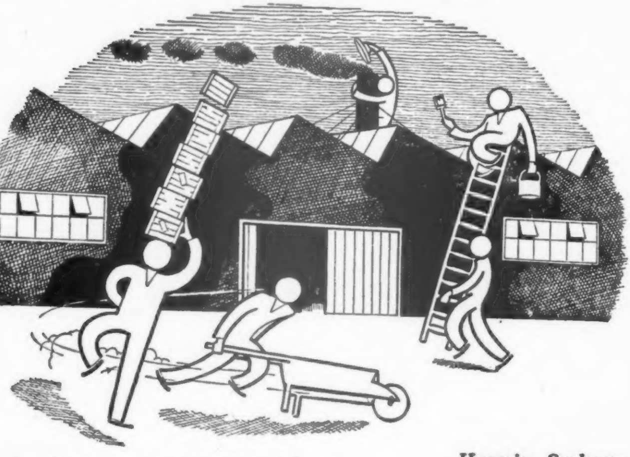


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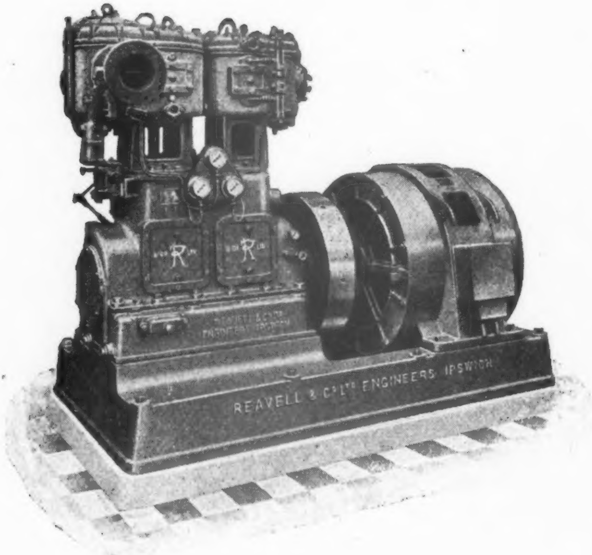

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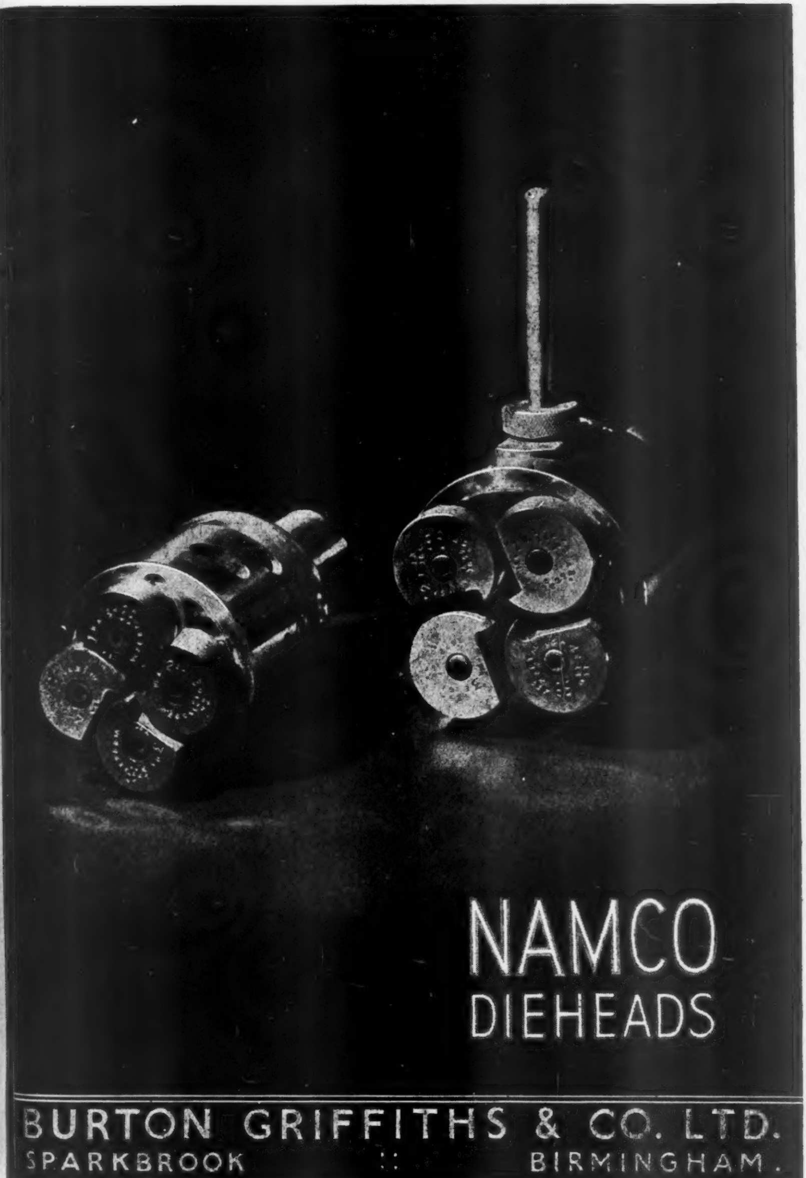
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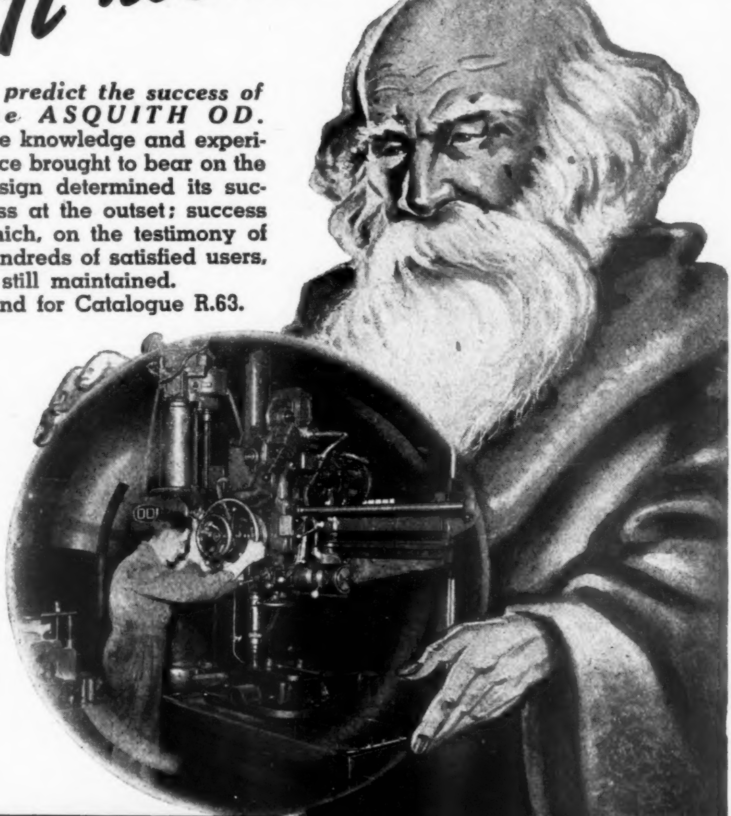


CRC 102B

INSTITUTION NOTES

February, 1942

Fixtures

March 4—Leicester Section. Lecture by Mr. J. D. Evershed, B.Sc., A.M.I.E.E., A.M.I.Mech.E., on "Factory Layouts."

March 7—Preston Section. Informal discussion on "Production Control."

March 11—Eastern Counties Section. Lecture by Mr. L. A. Childs, A.M.I.P.E., on "An Outline of Jig and Tool Design."

March 14—Yorkshire Section. Lecture by Dr. Geo. Schlesinger on "The University Training of Production Engineers."

March 14—London Graduate Section. Lecture by K. J. Hume, A.M.I.P.E., on "The Place of the Standards Department Relative to Production Engineering."

March 20—Meeting of the Council of the Institution, at Leicester.

Subscriptions Received for Research

Since the list in last month's "Notes" the following subscriptions for the work of the Research Department have been received:—

	£	s.	d.
W. B. Dick & Co....	5	5	0
British Timken Ltd.	25	0	0
R. J. H. Equipment Co., Ltd.	5	5	0
	£35	10	0

Graduateship Examination

It has been decided that instead of the usual Graduateship Examination at Easter this year, arrangements will be made similar to those adopted last year for the holding of internal examinations at various Technical Colleges throughout the country. Students preparing for the examination who have not been attending classes at the Colleges in question will be catered for wherever possible by arranging for them to take this substitute examination.

Production Engineering Courses

A large number of Technical Colleges have now made provision for the inclusion of a Production Engineering subject in the third year of their Ordinary National Certificate Courses in Mechanical Engineering. Certificates issued to successful students under this scheme will be countersigned on behalf of the Institution by our President.

Great interest has been shown in the suggested syllabuses for the Higher National Certificate in Production Engineering published in the December issue of *The Journal.* It should be stressed, however, that these are specimen syllabuses only. It

is not intended that they should be regarded by Technical Colleges as something that must be adopted without alteration. National Certificates are based on the results of internal examinations set by the Colleges themselves, and there is a good deal of latitude allowed as to the content of syllabuses, so long as a standard satisfactory to the Joint Committee in charge of the scheme is maintained.

It is disappointing to learn that the "Intensive Training Schemes" sponsored by the Board of Education and outlined in Lord Hankey's circular, to which attention was drawn in these "Notes" in November, have so far gained very little support. Colleges which were prepared to cater for the schemes have been unable to secure enrolments.

Examination Prizes

Mr. C. M. G. Calvert (Graduate) has kindly given a prize of £1 to be awarded for the best essay at the next examination to be held in substitution for our Easter Graduateship Examination.

Mr. F. Grover (Member), late President of the Yorkshire Section, has also kindly given two prizes of £2. 10s. each for successes at the examinations of the College of Technology, Leeds. One of these has been awarded to Mr. H. Wood, fourth and fifth years' Production Engineering Course, and the other to Mr. E. Spencer, second year (full time) day course, National Diploma.

Standing Committee of the Research Department

The Annual Meeting of the Standing Committee of the Research Department of the Institution was held in London on February 17th, Mr. J. H. Bingham (Chairman) presiding. The other members present were Dr. W. Abbott (Board of Education), J. E. Baty, E. J. H. Jones, W. J. Morgan (Machine Tool Trades' Association), J. D. Scaife, Dr. S. L. Smith (Department of Scientific and Industrial Research), M. H. Taylor, and Tom Thornycroft. The Director of the Research Department and the General Secretary were also present.

Various reports submitted were considered and adopted, and the Executive Committee and Finance Committee for the coming twelve months were appointed.

It was noted with satisfaction that the Research Department is now carrying out important work for more than one Government Department, and that the Report on Surface Finish is to be published at the end of February.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export

MATERIALS, CUTTING TOOLS, AND MACHINEABILITY INDEX*

By Dr. Geo. Schlesinger,
(Director of Research Department).

OF all the materials which have to be machined iron and steel are still by far the most important, so that in most cases the requirements for machining iron and steel must receive first consideration when selecting machines. This paper is devoted entirely to the machining of iron and steel to the exclusion of all non-ferrous metals.

The factors in machining shown in Fig. 1 are dependent on the machine tool, the tool and the material to be machined, that is, the workpiece. These factors can be calculated from the

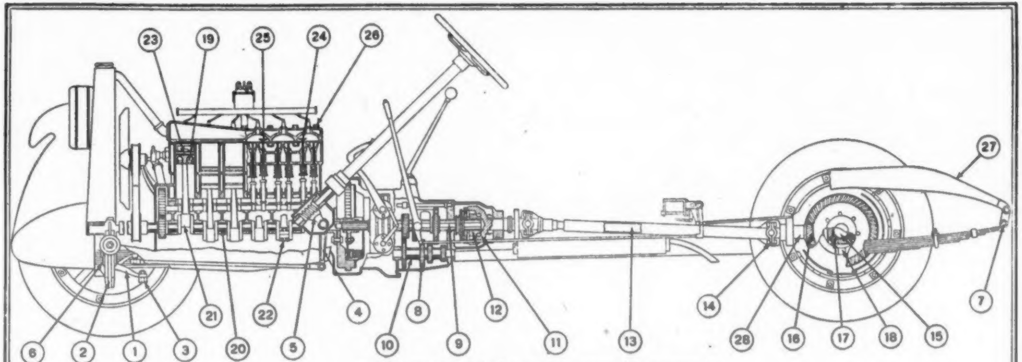
Factors in Machining		Distribution of Factors on :		
		Machine Tool	Tool	Workpiece
Cutting Power ($N=F \times v=M_d \times n$)		Driving Power	Heating	Heating
		Elements of Drive	Coolant	Coolant
F=Force	M_d=Torque	Resistance Deformation	Resistance Tool Life	Resistance Deformation
— x —	— —x— —			
v=Speed	n/min.=Revs.	(1) Existing Speeds (2) Vibration (3) Acceleration	Vibration Tool Life	Vibration

Fig. 1—Relation between the main factors in machining metals.

power supplied by the motor drive since the power of the motor is equal to the force on the tool x the cutting speed, or the turning moment x the number of revs./min. The knowledge of the value of these forces is of importance, for they influence the design of the machine, the life of the tool, the deflection of the workpiece, &c.

The cutting action creates heat at the working tip of the tool. Temperatures up to 1600°C (burning steel chips) are reached in the case of grinding. When using cemented carbides the temperature at the tip rises very quickly to between 600° and 800°C (red hot). This softens high-speed steels and changes the surface of the workpiece, creating a fragmented, non-crystalline and

* Paper read before a joint meeting of the Institution and the Society of Engineers and Metallurgists, Sheffield, November 15th, 1941 (Vol. XXI, No. 2, February, 1942).



Applications of nickel alloy steels in automobile construction.

1. Steering knuckle and steering arm SAE 2335, 3130, 3135, 3140	2. King pin SAE 2315, 2520, 3115, 4615	3. Steering ball stud SAE 2315, 2520, 3115, 3135, 3140	4. Steering gear arm SAE 2335, 3130, 3135, 3140	5. Steering gear and follower SAE 2315, 2512, 4615	6. Spring clips SAE 2335, 3135	7. Shackle bolts SAE 2315, 4615
8. Transmission gears SAE 2320, 2350, 2512, 3150, 3250, 3440, 4615, 4640	9. Transmission spline shaft SAE 2320, 2350, 2512, 3150, 3250, 4615, 4640	10. Transmission countershaft SAE 2315, 2512, 4615, 4640	11. Free wheeling pineapple 3½% NiMo	12. Free wheeling spider SAE 4615 3½% NiMo	13. Propeller shaft SAE 3130, 3140	14. Universal joints SAE 2315, 4615
15. Rear axle drive shaft SAE 2340, 3140, 3250, NiCrMo (.35/.40 C.)	16. Rear axle drive gear and pinion SAE 2315, 2512, 3115, 4615, 3½% NiMo, NiCrV	17. Rear axle differential gears SAE 2015, 2315, 3115, 4615	18. Differential cross SAE 2315, 3115, 4615	19. Piston struts 32% Ni (low expansion) steel	20. Crankshaft SAE 3140, 3240, NiCrMo	21. Connecting rods SAE 3135
22. Connecting rod bolts SAE 2330, 2350, 3130, 3140	23. Piston pins SAE 2315, 2512, 3115, 4615	24. Inlet valves SAE 3140	25. Exh'st valves 16 Cr, 14 Ni, (.60/1.20 C); 8 Cr, 20 Ni, 1 Si, (.40 C); 21 Cr, 12 Ni, 1 Si, (.25 C)	26. Engine bolts and studs SAE 2330, 3130, 3140	27. Frame (trucks and buses) SAE 3130	28. Roller bearings SAE 4620 NiCrMo

Fig. 2—Chassis of a motor car and the SAE steels used for 28 parts.

amorphous layer which forms a rough surface. For this reason the question of coolants is of considerable importance if the unfavourable influence of these high temperatures is to be reduced to a minimum without spoiling the tool. Another factor is the vibration which may be created by a combination of very high speeds and unbalanced rotating parts and are further accentuated by beds and supports which are not rigid and ineffective clamping devices on the toolpost. The foregoing are the most important mechanical factors for the machining process and they have, of course, a vital influence upon production results.

The machineability of the standard steels and especially the alloy steels exerts a great influence upon production economy in all workshops. In general, as the physical properties of materials are increased in order to make reliable components, so the difficulty of machining those components increases because the machineability of the material is worse. A considerable improvement in production efficiency would be achieved if steels were created which could be easily machined and which nevertheless had chemical constituents and physical properties which would ensure adequate strength and long life when subjected to the severe working conditions present in many parts of automobiles, planes, &c.

Nowadays, designers are frequently compelled to design components in which weight reduction is an important factor. To facilitate the production of these components materials are continually being developed with improved physical properties such as higher tensile strength, resistance to fatigue, &c. These physicals changes are usually accompanied by considerable increases in the machineability of the steels so that production costs become so high that they create serious limitations to the economical manufacture of units such as high-class engines. It is further desirable that producers and users of these refined steels should co-operate to restrict as far as possible the number of such materials. This restriction would lead to greater uniformity of composition and physical properties of steels supplied at different times and in different places, and would also reduce the cost of production. Another aim of this standardisation should be to select steels which have the required physical properties combined with a machineability within the economic limits of production. It is encouraging to note that in America in the last few years steels of high physical properties have been made which seem much easier and therefore cheaper to machine than the steels of similar physical properties commonly used on the continent and in Great Britain.

The American Standards Association together with the Society of Automobile Engineers standardised 284 kinds of steel, and in

STANDARD ALLOY STEELS (GERMANY)
FOR AUTOMOBILES.

Mark	Annealed		Hardened resp. heat treated			Chemical Constituents in %				
	Brinell Hardness H maximum	Brinell Resist'ce kg mm^2 maximum	Tensile Strength kg mm^2	Yield Point in % of the Tensile Strength minimum	% Elongation in 10" dia.	C	Ni	Cr	Mn	Si maximum
EN 15	162	55	60-80 Water	65	15-8	0.10-0.17	1.5±0.25	maximum 0.2	maximum 0.5	0.35
ECN 25	206	70	80-100 oil 90-110 Water	70 oil 75 water	14-10 oil 12-7 Water	0.10-0.17	2.5±0.25	0.75±0.2	maximum 0.5	0.35
ECN 35	220	75	90-120 oil	75	12-6	0.10-0.17	3.5±0.25	0.75±0.2	maximum 0.5	0.35
ECN 45	240	83	120-140 oil	75	10-5	0.10-0.17	4.5±0.25	1.1 ±0.2	maximum 0.5	0.35
VCN 15 w	206	70	65-76	65	16-13	0.25-0.32	1.5±0.25	0.5 ±0.2	0.4-0.8	0.35
VCN 15 h	206	70	75-85	70	15-12	0.32-0.40	1.5±0.25	0.5 ±0.2	0.4-0.8	0.35
VCN 25 w	220	75	70-85	70	14-10	0.25-0.32	2.5±0.25	0.75±0.2	0.4-0.8	0.35
VCN 25 h	220	75	80-95	70	12- 8	0.32-0.40	2.5±0.25	0.75±0.2	0.4-0.8	0.35
VCN 35 w	235	80	75-90	75	14-10	0.20-0.27	3.5±0.25	0.75±0.2	0.4-0.8	0.35
VCN 35 h	235	80	90-105	75	12-8	0.27-0.35	3.5±0.25	0.75±0.2	0.4-0.8	0.35
VCN 45	265	90	100-115	80	10-6	0.30-0.40	4.5±0.25	1.3 ±0.2	0.4-0.8	0.35

Fig. 3—German standardisation of chrome-nickel alloys for motor cars.

1939 published an interesting book* giving feeds, speeds, &c., for the machining of these materials under various conditions. We are of the opinion that the data given in this book are no longer up to date, for the development of super-rapid cutting tools and of cemented carbides has given rise to completely changed conditions.

A standardisation of materials in Great Britain has been attempted by the Directorate of Technical Development of the Air Ministry (D.T.D.) and the B.S.I. As the D.T.D. has over 300 specifications and the B.S.I. approximately 170, one naturally asks the question: " Are all these specifications necessary? "

It is appreciated that the requirements of designers must be recognised, nevertheless the importance of quantity production of steel by the steel maker and of components by the manufacturer of aircraft, munitions, &c., must come first. Some reduction in the number of specifications must be effected by eliminating unnecessary overlapping. Fig. 2 shows the chassis of a good American car in which the SAE specifications for 28 of the most important parts are given. The same material is often used for many parts, but it will be noted that e.g. the materials SAE 3130 to 3140 can be used for 12 parts, SAE 3315 for 11 parts, &c., and it is suggested that they tend to overlap, and since these materials (SAE 3130 to 3140) only differ by slight changes in the carbon content their number could be reduced in favour of standardisation. In the illustrated example seven materials would suffice for 28 components. However, it is true that the steelmaker needs the tolerances to facilitate both manufacturing and sales.

In Germany the number of Cr-Ni alloy steels was reduced from 60 to 11 by standardisation (Fig. 3). This made it much easier to carry out tests, such as cutting tests, within a reasonable time. Cutting tests on seven kinds of these materials and for six different chip areas, using high-speed cutting tools, based on a tool life of one hour, were carried out in order to find the best cutting angles and correct cutting speeds. These tests took 1½ years, so that it will be obvious that if the number of materials were increased to 200 or 300 the tests would take so long as to be almost impossible.

In order to keep in step with the continual improvement of cutting tools the Research Department of the Institution of Production Engineers started some time ago a comprehensive series of tests covering various machining factors, and with the specific object of determining the highest speeds for rough and finish turning with very good British cemented carbide tools. The basis of these tests is one hour tool life, and the range of speeds extends

* Manual on Cutting Metals (Single-point Lathe Tools), 1939, published by the American Society of Mechanical Engineers, New York, N.Y.

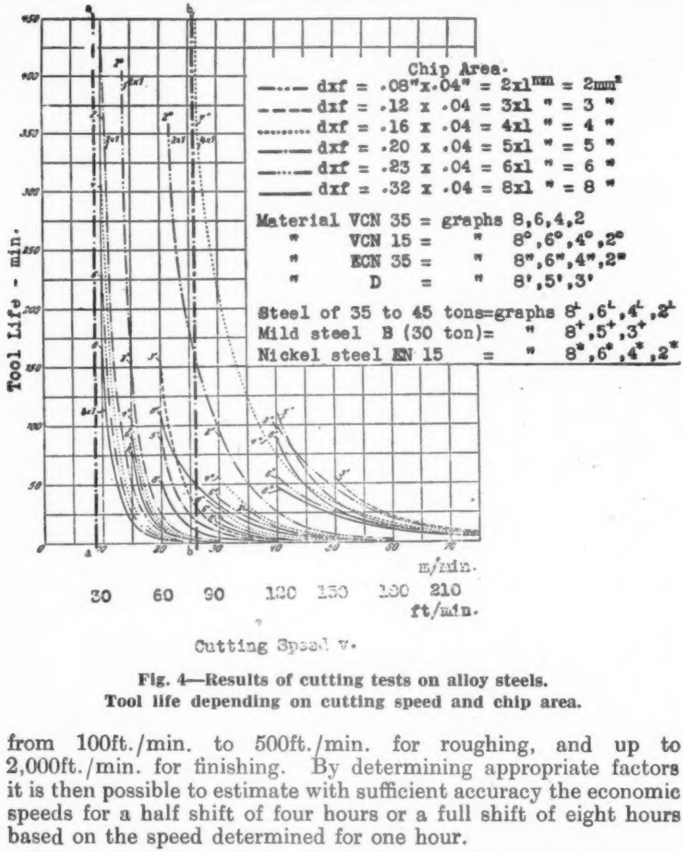


Fig. 4—Results of cutting tests on alloy steels.
Tool life depending on cutting speed and chip area.

from 100ft./min. to 500ft./min. for roughing, and up to 2,000ft./min. for finishing. By determining appropriate factors it is then possible to estimate with sufficient accuracy the economic speeds for a half shift of four hours or a full shift of eight hours based on the speed determined for one hour.

The results of a series of cutting tests are shown in Fig. 4. In these tests a constant feed of ·04in. was used with six different depths, varying from ·08in. to ·32in. The graphs show how cutting speed influences tool life in the case of these six different materials, all of which have been tested with the six different chip areas, using the most suitable cutting angles, causing the minimum cutting forces.

Each test was commenced with a speed so high that the tool life was only one minute, and the cutting speed was gradually

reduced until the tool life was increased first up to one hour and then up to a full shift of eight hours (about 400mins.). The position of the vertical asymptote to the hyperbolic tool life curve gives the speed at which the tool has an "indefinite" life. It is desirable to know the speeds for eight hours tool life under various conditions of cutting because by working at this speed it is possible to arrange for the replacement of tools and the regrinding without interruption during working shifts. These *economical* cutting speeds for hard, tough materials are also the basis for accurate *rate-fixing* as applied to the heavily stressed parts of automobiles, aeroplanes, &c. The physical properties ot the steels are given in the table Fig. 3. They vary between 162 Brinell hardness and 55kg./mm.^{2} (35 tons/sq. in.) tensile strength for steel EN15, up to 265 Brinell hardness and 115kg./mm.^{2} (75 tons/sq. in.) tensile strength for steel VCN45. In order to compare the Continental materials with the corresponding materials used in U.S.A., the Illinois Steel Chicago works supplied large rolls of SAE steels, 16in. diameter and from 7ft. to 10ft. long. The steels supplied were selected by the suppliers so as to correspond in physical properties, chemical analysis, and applications to the Continental steels with which they were to be compared. The range of SAE steels selected was: 2315, 2512, 3130, 3240, 3312, 4615, 5130, 5150, 6130. The properties are given in table Fig. 5.

As these materials were to be used for cutting tool tests the large diameters and lengths were desirable in order to have the longest possible cutting periods without interruption. Each time the tool is brought back to commence another cut, it has an opportunity to cool. This may be advantageous for the tool, but there is also the disadvantage associated with the shock to which the tool is subjected when cutting recommences.

The standard ECN and VCN analyses were prescribed for these materials, and when these analyses were rechecked before the cutting tests, it was found that the steel workers had maintained these analyses within very fine limits (see table Fig. 6).

To ensure uniformity of hardness, Brinell tests were taken for each reduction of diameter from 16in. down to 6in. As it was not practicable to take such a large heavy test piece to the Brinell press for testing each layer of material, a special portable Brinell press was used, which was fixed to the lathe on the rear slide, thus it was possible to test the specimen without removing it from the lathe centres (Fig. 7). Such frequent testing of Brinell hardness is absolutely essential for successful cutting tests. It is imperative to know either that the material is uniform or to know exactly how the hardness varies. Our experience has been that steel makers find great difficulty in maintaining uniform Brinell

Mark of Steel	ANALYSES: C	Mn	Basic open hearth Si	P max	S max	Ni	Cr	Va	Mo	BRINELL HARDNESS: Standard Values	Check Test heat-treated V.	Comparison of Machineability (Brinell)
SAE 2315	.10–.20	.30–.60	.15–.30	.04	.05	3.25–3.75	–	–	–	162	–	ECN 35 (155)
" 2512	.10–.20	.30–.60	.15–.30	.04	.05	4,75–5.25	–	–	–	158	–	
" 3130	.25–.35	.50–.80	.15–.30	.04	.05	1.00–1.5	.45– .73	–	–	156	206	
" 3240	.35–.45	.30–.60	.15–.30	.04	.05	1.50–2.0	.90–1.25	–	–	254	–	VCN 15 (237)
" 3312	.17 max	.30–.60	.15–.30	.04	.05	3.25–3.75	1.25–1.75	–	–	274	–	VCN 35 (292)
" 4615	.10–.20	.40–.70	.15–.30	.04	.05	1.65–2.00	–	–	.20–.30	122	–	EN 15 (125)
" 5130	.25–.35	.40–.70	.15–.30	.04	.05	–	.80–1.10	–	–	144	221	
" 5150	.45–.55	.60–.90	.15–.30	.04	.05	–	.80–1.10	–	–	178	248	
" 6130	.25–.35	.60–.90	.15–.30	.04	.05	–	.80–1.10	.15–.18	–	154	208	
" 6150	.45–.55	.60–.90	.15–.30	.04	.05	–	.80–1.10	.15–.18	–	168	252	

Fig. 5. Tested American S.A.E. Steels.

Chemical constituents and physical properties.

	C		Mn		Si		P		S		Ni		Cr	
Mark of Steel	Prescription	Check Analysis	Prescription	Check Analysis	Prescription	Check Analysis	Prescription	Check Analysis	Prescription	Check Analysis	Prescription	Check Analysis	Prescription	Check Analysis
EN 15	.10–.17	.15	≦.50	.53	≦.35	.27	≦.03	.015	≦.03	.025	1.5±.25	1.51	≦.30	.32
ECN 35	.10–.17	.14	≦.50	.51	≦.35	.33	≦.03	.015	≦.03	.030	3.5±.25	3.60	.75±.2	.89
VCN 15	.25–.32	.35	.4–.8	.72	≦.35	.38	≦.03	.02	≦.03	.025	1.5±.25	1.36	.5 ±.2	.7
VCN 35	.25–.32	.36	.4–.8	.59	≦.35	.38	≦.03	.02	≦.03	.031	3.5±.25	3.18	.75±.2	.89

Fig. 6. Comparison of Standard Prescriptions with Check Analyses.

(See table Fig. 3.)

hardness in such large specimens, and that variations of 10% are possible. Further, we had in one case hard inclusions (Fig. 8), which broke a tool, and in another case surface failures which made the piece useless (Fig. 9). So long as the Brinell hardness relating to each cut is known, the results can be modified to give a rational conclusion. The object of these tests was to try to standardise tool angles to give maximum cutting speed and minimum cutting forces for any given chip section. Other objects were longer tool life and better surface finish. Reduction in cutting forces is naturally accompanied by a reduction in power consumption for a given speed. This, in turn, is accompanied by a reduction in the heat produced, so that the tool edge remains cooler and it is not softened so soon.

One difficulty encountered in these tests was vibration of the long specimens when the critical diameter of the piece was reached

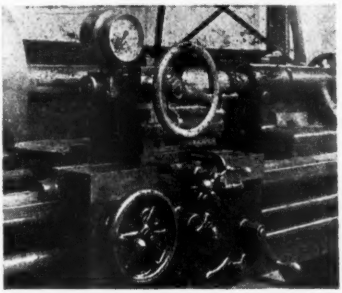


Fig. 7—Transportable Brinell Press on tool support.

(resonance) and the angle of plan too small. Despite the large diameter of 12in. there was considerable vibration in a workpiece of 10ft. length (Fig. 10). The use of steady-rests was not permissible since the whole length of the specimen had to be turned without interruption. Above and below the critical diameter the vibration ceased.

Deep roughing cuts, such as those shown in Fig. 11, where the chip area is 1·5 sq. in., are undesirable. Such a chip taken from a material with 210,000lb./sq. in. machineability index at a speed of 10ft./min. would require a drive of 150 h.p. This chip has actually been taken on a giant vertical boring mill. Although such chips are possible, the modern trend is to reduce the material allowance for machining to the absolute minimum, so that chips are as small as possible. Where deep cuts have to be taken it is desirable to adjust the feed in order to give a depth to feed ratio between 6:1 and 20:1. Such thin, flat chips bend easily, and

consequently give rise to smaller power consumption and increased tool life. It is important that the designer should arrange for castings and stampings to have the minimum machining allowances. Some parts, of course, such as the shaft of a steam turbine or a Diesel engine, may have large steps which call for heavy roughing cuts in the machining process, but this must be the exception and not the rule.

The vibration which occurred in the large (12in.) diameter specimen was found to be partly due to incorrect plan angles of the cutting tool (Fig. 12). With angles larger than 43° vibrations ceased almost for all diameters; thus it is clear that the British practice of using plan angles above 43°, as indicated in tool makers' catalogues, is justified. Increase of the plan angle (from 40° to 90°) decreases the downward pressure and the backward pressure, and has no significant effect upon the feed force.

Fig. 8—Hard inclusions, which broke the tool.

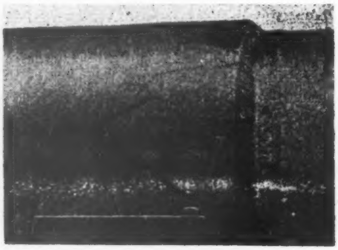


Fig. 9—Surface failures.

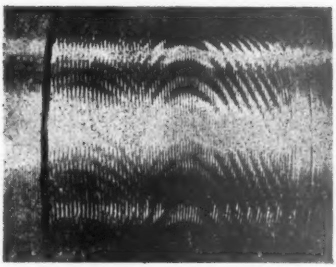


Fig. 10—Heavy vibration marks on surface on behalf of critical diameter and wrongly ground tool.

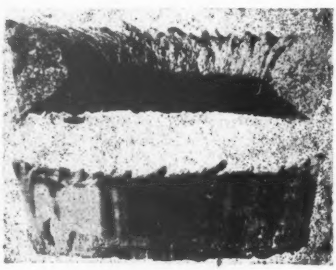


Fig. 11—Giant roughing chip of 1.5 sq. in. area (1,000mm.²), about 150 tons pressure.

As the result of these tests six combinations of tool angles in Germany were standardised (Fig. 13) in connection with the most used materials to be machined. A proposal for the British nomenclature is made in Fig. 14.

In America there exists also a proposal for the standardisation of the tool nomenclature (Fig. 15) containing only the symbols for the different tool angles in common use. It differs from the German in the essential item of the top rake angle. In the United

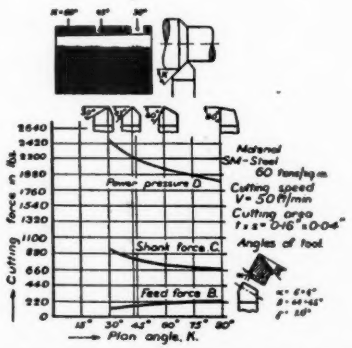


Fig. 12—Influence of angle of plan to vibration and forces.

Kingdom no such standardisation has yet been undertaken, but the catalogues of 10 leading tool making firms show that the same shapes are in common use. In effect, the standardisation of tool angles and tool shapes exists in Britain, although it is not officially recognised by the B.S.I. The tables Fig. 16 compare the shape, material, clearance angle, top rake angle, cutting angle, &c., for both crank round nosed turning tools and bar turning tools made by various firms. The shapes for e.g. 15 standard tools which should be supplied to every turner have been determined (Fig. 17/18), and there is no doubt that a committee of steel workers and important users, such as manufacturers of automobiles, aeroplanes, commercial vehicles, railway stock, electrical machinery, machine tools, &c., could be formed, and could determine in a very short time standardised angles relating to the accepted tool shapes and the various materials to be machined. Such a standardisation would be of great benefit to both makers and users of cutting tools. The *shank size* is limited by the distance between the centre line of the lathe and the top surface of the tool slide on which the tool must rest. Within

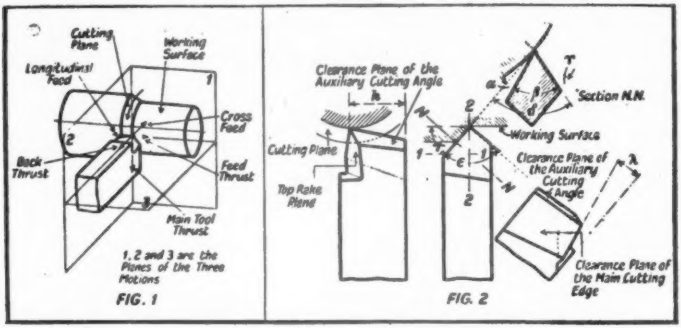


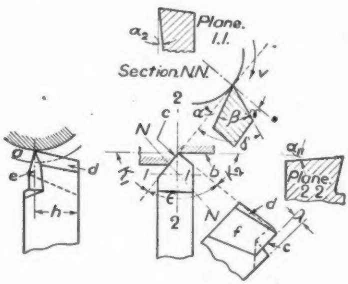
Fig. 13—Standardisation of tool angles in relation to materials in Germany.

TOOL ANGLES FOR VARIOUS MATERIALS

Clearance Angle a *deg.*	*Wedge Angle* β *deg.*	*Top Rake Angle* γ *deg.*	*Class of Material to be Machined*
6	84	0	Chilled Iron and Very Brittle Brass and Bronze.
8	74	8	Steel and Cast Steel of more than 45 tons per sq. inch Tensile Strength. Hard Cast Iron with Brinell Hardness Hn of more than 220. Cast Brass, Bronze and Yellow Brass.
8	68	14	Steel and Cast Steel of 32 to 45 tons per sq. inch Tensile Strength. Cast Iron of Brinell Hardness Hn of less than 180. Soft Yellow Brass.
8	62	20	Steel and Steel Castings of 22 to 32 tons per sq. inch Tensile Strength.
8	55	27	Tough and Soft Bronze. Very Soft Steel.
10	40	40	All Soft Metals. Pure Aluminium.

these limits the tool shank should be made as strong as possible in order to eliminate vibration. The similarity of round, square, and rectangular shanks made by British tool makers is shown in Fig. 19a, b. For comparison, practice of five American firms is also given.

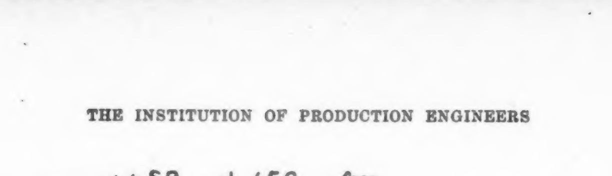
The material used for tool shanks should be good carbon tool steel of at least 60 tons/sq. in. tensile strength. Even this grade of steel is not adequate for high-speed roughing cuts on tough Ni-Cr steel. In the latest tests carried out by the Research Department it was found that when roughing Ni-Cr steel with approximately $3\frac{1}{2}\%$ Ni and a Brinell hardness of 320 the front edge of the tool shank was worn down about $\frac{1}{8}$in. after only one hour's test, consequently we recommend that for these circumstances special shanks should be used having a tensile strength of 80 to 90tons/sq in.



a = Clearance Angle (Perpendicular to Cutting edge)
a_1 = Front Clearance Angle
a_2 = Side Clearance Angle
β = Tool Angle
γ = Top Rake Angle
δ = Real Cutting Angle $= a_1 + \beta$
ϵ = Angle at Point
k_1 = Cutting Angle in Plan (Setting Angle)
k_2 = Back Setting Angle
λ = Back Rake Angle
v = Cutting Speed
a = Cutting Plane
b = Machined Surface
c = Main Cutting Edge
d = Clearance Plane of Back Cutting Edge
e = Top Rake Plane
f = Clearance Plane of Main Cutting Edge
h = Height of Cutting Point

Fig. 14—Proposal for British Nomenclature.

In the tests at present being carried out by the Research Department the effect of changing cutting angles upon the forces on the tool was determined by means of tool dynamometers. Two dynamometers are used: a small one shown in Fig. 20 for measuring cutting forces down to $\frac{1}{2}$lb., and a large one, Fig. 21, for measuring cutting forces from 200lbs. up to 3 tons. The design of the mechanical part of these two dynamometers is shown in the sectional drawing, Fig. 22. The arrangement of this dynamometer is similar to that of the Schiess-Defries dynamometer, but some changes have been made which were essential to enable the new



Nature of material to be machined.	Front clearance. "F.C."	Side clearance. "S.C."	Side rake. "S.R."	Back rake. "B.R."
Cast iron—soft	3 to 5	2 to 4	4—8	0—4
Cast iron—hard	3 ,, 5	2 ,, 4	3—6	—
Semi-steel	3 ,, 5	2 ,, 4	3—6	—
Cast nickel iron	3 ,, 5	2 ,, 4	3—6	—
Chilled cast iron	3 ,, 5	2 ,, 4	3—6	—
Malleable iron	3 ,, 5	2 ,, 4	4—8	0—4
Yellow brass	4 ,, 6	3 ,, 5	0	—
Ordinary bronze	4 ,, 6	3 ,, 5	4—8	—
Bronze alloys	4 ,, 6	3 ,, 5	4—8	—
Cast aluminium	6 ,, 8	3 ,, 5	10—20	10—20
Aluminium alloys	6 ,, 8	3 ,, 5	10—20	10—20
Non-metallics	6 ,, 8	3 ,, 5	6—10	2—6

Fig. 15—Proposal for American Nomenclature. Clearance and rake angles.

electrical elements to function correctly. The electrical units for both dynamometers have been recently developed and have been made by British firms. By means of these dynamometers the oblique cutting force is resolved into three components, each of which are measured separately. The main component is the vertical downward force (F_v), which determines the power required to carry out the cutting process. There are also components in the direction of the feed (B) and of the shank (C), which, according to the Schlesinger criterion, determine the tool life, but do not affect the power consumption perceptibly. The three components are mutually perpendicular. Changes of top rake, side rake, or clearance influence these cutting forces, and the instrument indicates clearly which angles are most suitable for any given material. Each material requires different angles, but it is often possible to group a number of materials together for which the cutting angles are sensibly the same. This is very desirable because it is not practicable to supply a machine tool operator with sufficient tools to have different angles for each material which is to be machined. By suitable grouping of the materials it is possible that about six different sets of tool angles will prove sufficient to cover the whole range of materials machined, from the hardest cast iron to the softest white metal (see Figs. 13 and 16). Only by tests such as those described above is it possible to determine the four main cutting angles, namely: clearance

angle α, tool angle β, top rake angle γ, and angle of plan k (setting angle).

Before effective standardisation of the values of tool angles can be made it is desirable to have a standardisation of nomenclature. All engineers should use the same names and symbols for the various angles, planes, and forces relating to cutting tools (see Fig. 14). The necessity for reducing tool shapes to the absolute minimum is accentuated by the increasing use of cemented carbide tools. If these tools are to be manufactured on an economical basis for small workshops, standardisation of tip shapes is essential, otherwise the cost of introducing these tools will be prohibitive. An ordinary tool with a shank 1in. × ⅝in., suitable for a moderate sized lathe, has an average cost of approximately 25s., so that the cost of the tools required for a workshop of 20 machines and operators, allowing between 20 and 30 for each operator, and a similar number in stock, would be approximately £1,400. If a director is convinced that he can increase the output of his 20 machines from 30 to 50% by using modern high-speed tools he will not hesitate to buy them. Fig. 23a, b, show the number of tools necessary for 20 workers engaged on both roughing and finishing operations, and show how these tools, ordinary and special, should be distributed among the men and in the storeroom.

As the example refers to an old workshop, high-speed tools were mostly introduced and only a few tungsten carbides. Because ordinary high-speed or super high-speed tools are generally hardened by the user himself, it is to be recommended that the hardened and ground tools are checked for correct hardness by the Rockwell or Vickers hardness tester (Fig. 24).

Standardisation of the shapes of cutting tools will not in any way handicap good steel makers. There is no doubt that although tools may have identical shapes they will have very different tool lives and efficiencies, depending upon the grades of steel used. The individuality of the tool makers will be expressed in the grades of steels and their heat-treatment, and not in variety of tip form.

Tool life depends on: (1) cutting speed, (2) machineability of the material, (3) the chip cross section. Cutting speed and tool angles are interdependent, and the best angles and speeds for a given material can only be specified when the machineability of that material is known. The definition of "machineability index" is based on the formula $\frac{1 \times q \times v}{33{,}000 \times \eta} = N$, where I = the machineability index (specific cutting pressure in kg./mm.^{2} or lbs./sq. in.), N = the net h.p. of the motor, v = the cutting speed in f.p.m., η = the efficiency of the machine, and q = the chip area. The chip area is given by the depth of cut × the feed per rev. or per stroke. Generally

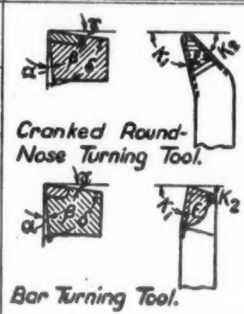
Firm	Material	Clearance α deg.	β deg.	Top rake γ deg.	δ deg.	Shape ε deg.	Plan k_1 deg.	Plan k_2 deg.	λ
Edgar Allen & Co.Ltd (Stag Allenite)	 Cranked Round-Nose Turning Tool. Bar Turning Tool.	6 6 6	81 76 71	3 8 13	87 82 77	30 " "	105 " "	45 " "	
English Steel Corp.Ltd (Escaloy)		6 6 6	80½ 76 71	3½ 8 13	86½ 82 77	30 " "	105 " "	45 " "	
Alfred Herbert Ltd. (Ardoloy)		6 6 6	80½ 76 71	3½ 8 13	86½ 82 77	30 " "	105 " "	45 " "	
Arthur Balfour & Co.Ltd (Balfalloy)		6 6 6	81 76 71	3 8 13	87 82 77	30 " "	105 " "	45 " "	
Osborne & Co.		5 6 7	82 75 68	3 9 15	87 81 75				
Jones & Colver (Novite)	Cast iron; high silicon; carbon steel. 45-55tons/sq.in. and 55-65 tons/sq.in. Gunmetal.			3-5					
	Cast iron 250-400 Brin.			5					
	Cast iron 180-250 Brin.			8					
	Chilled, malleable, pearlite iron. Hardened high speed steel, 165 tons/sq.in.			0					
	Manganese steel, 12% Nickel chrome steel, 55,70 & 90 tons/sq.in.			0-5					
	Carbon steel, 25-35 and 35-45 tons/sq.in. Brass-cast. Soft brass. Bronze.			3-8					
	Cast steel, 65 tons/sq.in. Chrome vanadium steel, 65 tons/sq.in. Wrought iron, phosphor bronze.			8-15					
	Non-ferrous metals			13-15 13-20					

Fig. 16.
Shapes and angles of crank round-nosed turning tools of various firms.
Shapes and angles of bar turning tools of various firms.

Firth & Brown.	Black bar, rough stampings, and forgings (over 50 tons/sq.in.tensile). Steel castings. High tensile alloy steels. Manganese steel (12% Mn.)	4-6	84-81	0-3	90-87	30	105	45	
	Black bar, rough stampings, and forgings (up to 50 tons/sq.in.tensile). Metal free from scale, blowholes,etc.(over 50 tons/sq.in.tensile). Chilled and special alloy cast irons.	"	81	3	87	"	"	"	
	Stainless and "Staybrite" steel forgings and bar.	"	87-79	3-5	87-85	"	"	"	
	Soft grey, close grained cast iron; slate and glass.	"	81-76	3-8	87-82	"	"	"	
	Metal free from scale, blowholes etc.(up to 50 tons/sq.in. tensile).	"	79-76	5-8	85-82	"	"	"	
	Copper, soft brass.	"	69	15	75	"	"	"	
	Aluminium alloys.	"	69-60	15-24	75-66	"	"	"	
A.C. Wickman,Ltd., (Wimet).		3-4	83-84	3	86-88	30	105	45	
		4-5	77-78	8	81-83	"	"	"	
		4-5	73-74	13	77-79	"	"	"	
Cutenit/Jessop.	Steel up to 40 tons/sq.in.	10-12	68-72	8-10	78-84	30	105	45	
	" from 41-52 " " "	8-10	72-74	6-8	80-84	"	"	"	
	Cast steel of 63 tons. Steel from 53-62 tons/sq.in. Cast iron to 180 Brin.	8-10	74-76	4-6	82-86	"	"	"	
	Ni-Cr. and Alloy Steel								
	47-62 tons/sq.in.	6-8	76-78	4-6	82-86	"	"	"	
	63-90 -do-	6-8	78-80	2-4	84-88	"	"	"	
	91-127 -do-	6-8	80-82	0-2	86-90	"	"	"	
	12% Manganese steel	6-8	80-82	0-4	86-90	"	"	"	
	Cast iron 180-250 Brin.	8-10	76-80	2-4	84-90	"	"	"	
D. Hinton,Ltd. (Wimet)		6	81	3	87	30	105	45	
		6	76	8	82	"	"	"	

Fig. 16.
Shapes and angles of crank round-nosed turning tools of various firms.
Shapes and angles of bar turning tools of various firms.

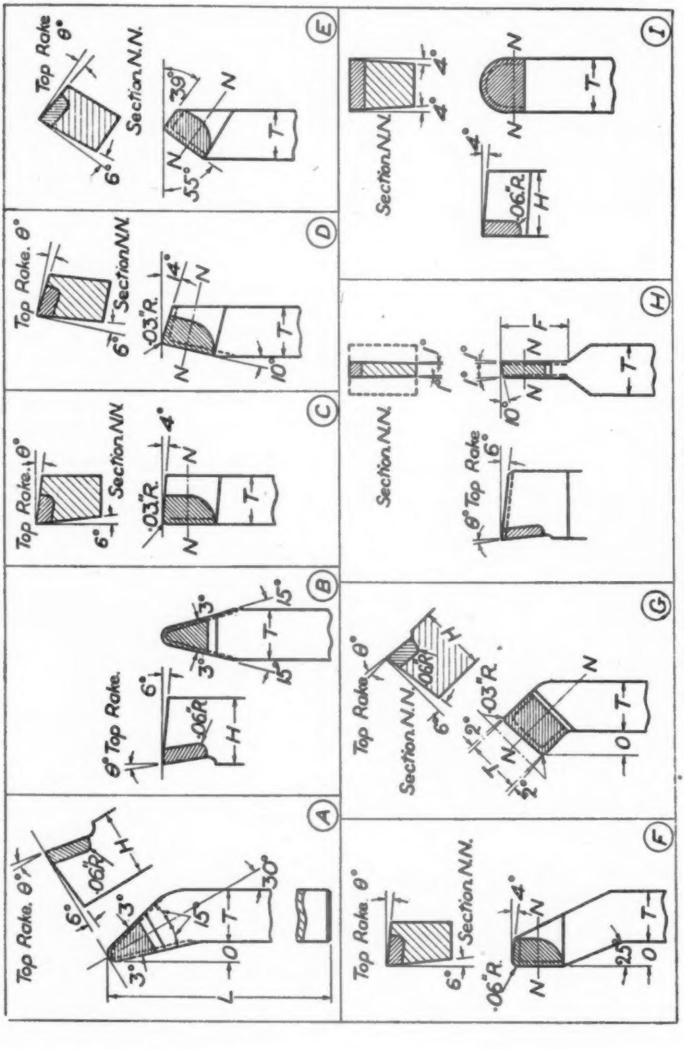


Fig. 17—Shapes of external turning tools.

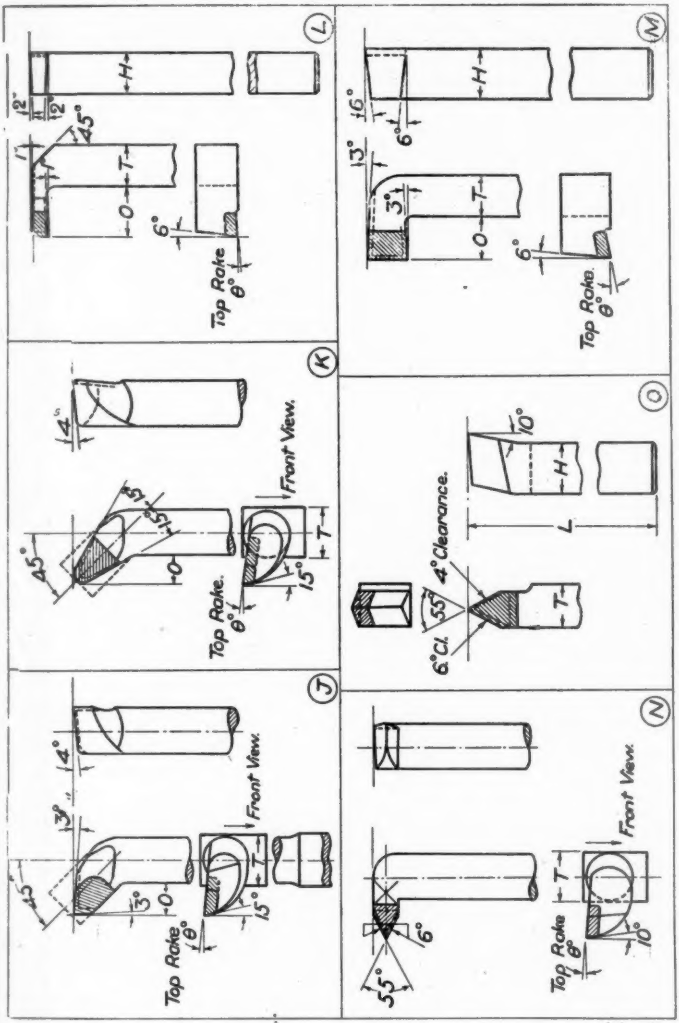


Fig. 18—Shapes of internal and threading tools.

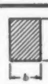
C

we take $\eta = \cdot 6$ as the average value for ordinary machine tools, then $33{,}000 \times \cdot 6 = 20{,}000$, and the formula becomes $\frac{1 \times q \times v}{20{,}000} = N$. The areas of chip are inscribed in Fig. 4. For ease of comparison the feed per rev. was kept constant at ·04in., and care was taken to keep the relation of $\frac{\text{depth}}{\text{feed}}$ greater than 4:1 for roughing cuts. This rule has been adopted for all these Continental cutting tests, with the exception of the two smallest chip areas.

The machineability index is the figure which determines the maximum permissible cutting speed for any material when finish-

BRITISH

Shank Sizes

	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"		
	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"	1 1/4"	1 1/2"	2"
	b/h Ratio	1:1.2	1:1.25	1:1.33	1:1.4	1:1.5	1:1.6	1:1.66				
		1 1/4"x1 1/2"	3/4"x1" 1 1/2"x2"	1 1/4"x1 3/4"	1/2"x3/4" 1"x1 1/2"	5/8"x 1"	3/8"x5/8" 3/4"x1 1/4"	1"x 1 1/4"				
		Parting and Recessing Tools										
	b/h Ratio	1:3.33	1:4	1:5	1:5.33	1:8						
		3/8"x1 1/4"	5/16"x1 1/4"	1/4"x1 1/4"	3/16"x 1"	1/8"x 1"						

Escaloy Ardoloy. Steg Allenite. Hinton "Wimet" Wickman "Wimet"
Cutenit. Firth Brown. Jones & Colver.

U.S.A.

	1/4"	5/16"	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1 1/4"	1 1/2" S.	1 3/4" S.
	b/h Ratio 1:1.2	1:1.25	1:1.33	1:1.5	1:1.6	1:1.66	1:2				
	5/8"x3/4"S. 1 1/4x1 1/2"S.	1"x1 1/4"	3/4"x1"S.	1"x1 1/2" 1/2"x3/4"S	5/8"x1"S.	3/4"x1 1/4"S.	1/2"x 1" 5/8"x1 1/4" 3/4"x1 1/2" 1"x2"				

S = Stellite only

Firth Sterling. Carboloy. Ex-cell-o. Stellite. Kennametal.

Fig. 19 (a, b)—British and American shank sizes.

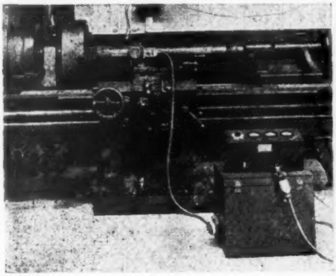


Fig. 20—Small tool dynamometer from ¼lb. to 1.2 tons pressure.

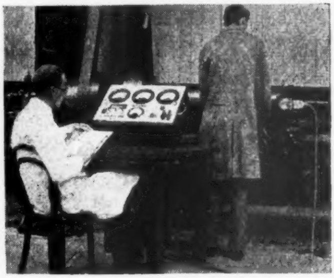


Fig. 21—Large tool dynamometer from 100lb. to 3 tons pressure.

ing or roughing with selected chip areas, and when using a given kind of tool with correct cutting angles.

The machineability index I was determined by dividing the measured vertical force F_v by the measured chip area $q : I = \frac{F_v}{q}$. The vertical force is directly proportional to the h.p. for the particular cut concerned. Fig. 25a, b, show that this machineability index I (last column) is fairly constant over a wide range of chip

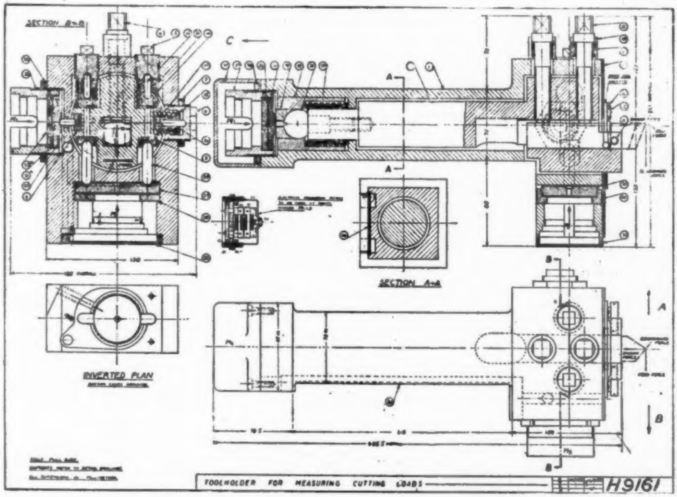


Fig. 22—Sectional drawing of tool dynamometers.

b

ORDER TABLE FOR STANDARD HIGH-SPEED TOOLS FOR 20 LATHES

Turning operation	Shape	Section of shank, ins.	Number of tools . service and stock											
			For soft and semi-hard steels; tensile strength, 22–32 tons per sq. in.			For hard steels; tensile strength, 33–45 tons per sq. in.		For cast iron, Brinell hardness number less than 115	For bronze and yellow brass			Total number of tools		
			High-speed tools, "tough" roughing	High-speed tools, "hard" finishing	Tungsten carbide tools, tons per sq. in. tensile strength	High-speed tools, "tough" roughing	High-speed tools, "hard" finishing	Tungsten carbide tools, tons per sq. in. tensile strength	High-speed tools, "tough" roughing	High-speed tools, "hard" finishing	Tungsten carbide tools, tons per sq. in. tensile strength	In use	Stock	Total
Roughing, right-hand		5/8 - 1 3/4 - 1 3/16 1 - 1 3/8	28 (14)* 8 (4) 4 (2)			28 (14)* 8 (4) 4 (2)	14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	4 (2)*	4 (2)*		84 32 12	42 16 6	126 48 18
Roughing, left-hand		5/8 - 1 3/4 - 1 3/16 1 - 1 5/8	14 (7)* 4 (2) 2 (1)			14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	4 (2)*	4 (2)*		56 24 8	28 12 4	84 36 12
Finishing		5/8 - 1 3/4 - 1 3/16 1 - 1 3/8												
Facing, right-hand		5/8 - 1 3/4 - 1 3/16 1 - 1 3/16	24 (14)* 8 (4) 4 (2)			28 (14)* 8 (4) 4 (2)	14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	4 (2)*	4 (2)*		84 32 12	42 16 6	126 48 18
Facing, left hand		5/8 - 1 3/4 - 1 3/16 1 - 1 3/8	14 (7)* 4 (2) 2 (1)			14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	14 (7)* 4 (2) 2 (1)	4 (2)*	4 (1)*		56 22 8	28 11 4	84 33 12
Boring		φ 3/8 9/16 5/8 3/4 1 1 3/16					12 (6)* 12 (6) 12 (6) 12 (6) 2 (2) 2 (2)			4 (2)* 4 (2) 4 (2)		12 12 12 16 6 6	6 6 6 8 4 4	18 18 18 24 10 10
Boring, facing		φ 3/8 9/16 5/8 3/4 1					12 (6)* 12 (6) 12 (6) 12 (6) 2 (2)			4 (2)* 4 (2)		12 12 12 16 6	6 6 6 8 4	18 18 18 24 10
											Totals	552	279	831

* The numerals in brackets denote the number of tools in stock.

Fig. 23a.

areas for both turning and shaping operations. If these indices were known for each material they would be of considerable use in the rate-fixing office. The rate-fixer would be able to specify the cutting speed, the chip area, the tool to be used on any given lathe, shaper, or other machine tool. The index would also provide another objective for the steel maker, who would attempt to produce steels which had not only given chemical analyses and physical properties, but also machineabilities within economic limits. The lower the machineability index the easier the material is machined, and the more satisfactory is that material from the manufacturers' point of view.

During the years 1940 and 1941 roughing and finishing tests have been carried out by the Research Department in the work-

ORDER TABLE FOR SPECIAL RAPID TOOLS FOR 20 LATHES

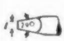
Turning operation	Shape	Section of shank, ins.	Number of tools: in use and in stock					
			For steels, cast iron, and bronze			Total number		
			Rapid, "tough" roughing tools	Rapid "hard" finishing tools	Tungsten carbide tools	In use	Stock	Total
Round-nose		r = 1/8 3/16 1/4 1/2	10 10 10 5	5 5 5 3			15 15 15 8	15 15 15 8
Grooving offset, right-hand		ℓ = 5/64 1/8 5/32 1/4 SECT. = 5/8 × 1	10 20 10	5 10 5	 5 	9 20 9	6 10 5 6	15 30 5 15
Grooving offset, left-hand		ℓ = 1/8 1/4 SECT. = 5/8 × 1	20 10	10 5		20 9	10 6	30 15
Radius tool		r = 1/8 3/16 SECT. = 5/8 × 1	10 6	5 3			15 9	15 9
Internal grooving (sharp)		ℓ = 1/8 3/16 5/16 SECT ∅ = 3/4	6 6 6	3 3 3		5 5 5	4 4 4	9 9 9
Internal grooving (round)		r = 1/8 3/16 SECT. ∅ = 3/4			5 5		5 5	5 5
Threading (U.S.A.)		∅ = 1/2	16	8	6	18	12	30
Threading (Whitworth)		∅ = 1/2	10	6	6	11	11	22
Threading (Acme)		ℓ = 0,082 0,087 0,143 0,165 SECT. ∅ = 1/2	4 4 4 4 4			2 2 2 2 2	2 2 2 2 2	4 4 4 4 4
					Totals	121	175	296

Fig. 23b.

shops of the L.M.S. Railway Company at Derby. For these experiments a testing lathe with an average h.p. of 30 and a maximum of 48, and with an infinitely variable speed ranging from 20 r.p.m. to 730 r.p.m., was used. The tools used in these tests were hard cemented carbide-tipped tools of first-class British make. The materials machined were: (1) 36 tons/sq. in. heat-treated axle steel, (2) 60 tons/sq. in. hard manganese steel (S), and (3) 80 tons/sq. in. 3% Ni-Cr steel (N). Fig. 26 gives the analyses of these steels. We found the machineability index for SU material and NU material was approximately 210,000lbs./sq. in., and for the SJ and NJ material, which was much harder, the index was approximately 400,000lbs./sq in. Using the same tool, the same shape, and the same angles, it was observed that the cutting speed for one hour's tool life for the S material was approximately 200ft./min., and for the Ni-Cr material approximately 180ft./min.

Finishing cuts are at present in progress, but the preliminary tests show that with finishing cuts ·04in. deep and ·01in. feed speeds between 400ft./min. and 800ft./min. were attained, and the machineability index rose to values as high as 830,000lbs./sq. in. (Fig. 27; Test Nos. 21 to 24). A comprehensive report of the Research Department is in course of preparation.

In cutting Ni-Cr steel at approximately 180ft./min. with a chip section ·375in. deep, ·042in. feed (see Fig. 27; Tests 33 to 39), we encountered the difficulty of swarf removal (Fig. 28a, 28b). We are of the opinion that the only safe practical method of swarf removal is by so shaping the tool that no dangerous swarf is created. The chip breaker notch can be ground in the tool without changing the general form of the tip. It is obvious that the depth, width, and inclination of the chip breaker notch vitally affected its efficiency. These factors form the subject of a special research now being undertaken by the Research Department.

Fig. 24—Checking the correct Rockwell hardness of high-speed tools.

During the tests mentioned above we were able to change from the long dangerous flowing chips shown in Fig. 28 (*a*) to the slow coiled chips shown in Fig 28 (*b*). The diameter of the chip coils can be regulated by altering the chip breaker. The most convenient form of chip flow is that in which it passes steadily past the tool support without touching the workpiece or endangering the operator. The saw-like teeth on the chips are dangerous (see Fig. 11) both to the workpiece and the operator, and in the case of tougher materials have an adverse effect upon the tool shank. For this reason it is desirable to keep the chip coils sufficiently small to enable them to remain within the tip length and not to rub against the tool shank. When taking roughing cuts with a cutting speed of 200 f.p.m. and a 1½in. diameter chip coil, a continuous coil about 40in. length per minute was created. If this process goes on for one hour we have 2,400ft. of chip, whereas when the chip is not coiled, but is straight and flowing, we have

1	2		3		4		5		6		7		8	9	10	11		12		13		14	
													POWER			FORCES = F						Machineability Index $I = \frac{Fv}{q}$ specific pressure	
No. of test	f Feed constant mm	in.	d Depth of cut mm.	in.	q Area of chip mm²	sq. in.	Dia. of workpiece mm.	in.	Revs./min. of Motor	Spindle	v Peripheral speed m./min.	ft./min.	Gross inp't kW	Net O'put kW	Effi-ci'cy %	Vertical Fv Kg.	Lbs.	Shank Fc Kg.	Lbs.	Feed Fb Kg.	Lbs.	Kg./mm²	1000 lb./sq.in.
1	0.9	.035	1.93	.076	1.74	.0027	143.0	5.62	1488	494	22.2	72	1.90	1.094	57.5	300	660	165	363	75	165	172	241
2	0.9	.035	1.93	.076	1.74	.0027	121.0	4.80	1488	494	18.8	61	1.65	0.900	54.5	293	645	150	330	75	165	168	235
3	0.9	.035	2.90	.114	2.61	.0040	162.6	6.40	1482	492	25.2	82	2.89	1.910	66.2	465	1002	225	495	135	296	178	249
4	0.9	.035	2.98	.117	2.68	.0041	144.0	5.66	1482	492	22.3	73	2.64	1.700	63.6	465	1002	205	452	125	176	173	242
5	0.9	.035	4.00	.158	3.60	.0055	170.4	6.70	1472	487	26.2	85	3.69	2.690	67.6	628	1380	295	650	180	394	174	244
6	0.9	.035	4.00	.158	3.60	.0055	127.5	5.00	1482	492	19.8	64	3.00	2.020	73.2	680	1500	285	630	220	485	189	266
7	0.9	.035	4.80	.189	4.32	.0066	146.2	5.75	1473	488	22.3	72	4.13	2.890	70.3	790	1750	340	748	160	352	183	257
8	0.9	.035	6.80	.267	6.12	.0093	152.2	6.00	1472	488	23.1	74	5.57	3.880	69.7	1025	2250	400	880	247	542	168	235
9	0.9	.035	6.70	.265	6.03	.0092	132.8	5.22	1462	485	20.2	66	4.93	3.390	68.8	1025	2250	410	900	247	542	170	238
10	0.9	.035	7.80	.307	7.02	.0108	132.2	5.20	1462	485	20.1	65	5.50	3.790	68.8	1150	2520	445	980	290	638	164	230
			Exact measurements of the true cutting depth are difficult to be made. consequently the exact area of chip is not certain.																	Average		174	244

Fig. 25a.—Machineability tests on steel of 32 ton/sq. in. tensile strength on a lathe with constant feed (2) and varying depth of cut (3) keeping the peripheral speed (7) fairly constant. The last column (14) contains the *machineability index.*

1	2	3		4		5		6	7	8	9		10	
								POWER					Machineability Index $I = \frac{Fv}{q}$ specific pressure	
No. of test	Number of strokes per min.	Length of stroke mm.	in.	Cutting speed (average) m./min.	ft./min.	Chip section = q Depth × feed mm. mm.	Depth × feed* in. in.	Input to motor kW	Net work of tool kW	Degree of efficiency %	Force Fv Kg.	Lbs.	Kg./mm²	1000 lb./sq.in.
1	12	550	21.65	10	33	Idle	—	2.66	—	—	—	—	—	—
2	,,	,,	,,	,,	,,	1 × 1	.04 × .04	3.64	0.655	18	170	373	170	238
3	,,	,,	,,	,,	,,	2 × 1	.08 × .04	4.18	1.330	32	345	755	173	242
4	,,	,,	,,	,,	,,	3 × 1	.12 × .04	5.26	2.010	39	522	1145	174	244
5	,,	,,	,,	,,	,,	4 × 1	.16 × .04	5.74	2.560	44.5	700	1540	175	245
6	,,	,,	,,	,,	,,	4 × 1.25	.16 × .05	7.29	3.290	46	855	1880	171	239
7	,,	,,	,,	,,	,,	4 × 1.5	.16 × .06	8.43	3.930	47	1020	2250	170	238
8	,,	,,	,,	,,	,,	4 × 2	.16 × .08	9.63	5.270	55	1376	3020	172	242
9	,,	,,	,,	,,	,,	5 × 2	.20 × .08	11.27	6.580	58	1720	3770	172	241
10	,,	,,	,,	,,	,,	6 × 2	.24 × .08	13.22	7.870	59.5	2040	4480	170	238
							* Calculated from measured mm.					Average	172	242

Fig. 25b.—Machineability tests on steel of 32 ton/sq.in. tensile strength made on a crank shaper keeping the cutting speed (4) constant = number of strokes (2) per minute × length of stroke (3) constant varying the chip section (5). The last column (10) contains the *machineability index.*

to handle 11,000ft. of chip. One should not overlook the fact that these chips are very hot (often between 300° C. and 400° C.), so that the temperature alone constitutes a source of danger. It is not unreasonable to say that in a great many shops the problem of swarf disposal constitutes one of the greatest hindrances to the extended use of cemented carbide tools. We have found that all artificial chip breakers, brazed, welded, or screwed to the tool or toolpost, are inferior to the natural chip breaker ground in the tool tip. Some artificial chip breakers frequently result in the formation of short flat chip spirals, which tend to spring away from the workpiece as they break off, and constitute an added danger to the machine operators in the vicinity.

Tests have been carried out on the Continent to try and relate *Brinell hardness* to machineability and tool life for nickel-alloy steels (Fig. 29). The horizontal axis of this graph represents the Brinell hardness and the vertical ordinates represent the cutting speed in ft./min. based on a tool life of one hour. The graphs

Raw Materials.

(a) S-material - 60 ton/sq.in. tensile.

2 kinds of S-material were provided in round bars, 12" dia. approx. 4' long, heat treated.

MAKER		Dia	ANALYSIS								
			C	Mn	Cr	Si	Ni	S	P	Brinell hardness	
										Declared by client	Checked by R.D.
(1)	J	12"	.36	.95	.08	.19	.18	.029	.036	179/197	
(2)	U	12"	.59	.80	-	.297	-	.044	.044	275	217/235

(b) Chromium-Nickel Steel-80 ton/sq.in. tensile; heat treated.

MAKER		Dia	ANALYSIS									
			C	Mn	Cr	Ni	Si	Mo	S	P	Brinell		
											Declared	Checked	
(1)	J	5"	.29	.56	1.27	3.27	.26	.41	.033	.025	363/375	351/429	not uniform very hard scale.
(2)	U	8"	.31	.57	.72	2.74	.208	.50	.032	.033	248	235	

(c) Axle Steel - 36 ton/sq.in. tensile; heat treated.850°cooled in air.

MAKER	Dia	C	Mn	Si	Cr	Ni
R	8"	.26	.65	.15	-	-

Fig. 26 (a, b, c)—Analyses of S-material, Cr-Ni steels and axle steel.

represent a comparison of the German Ni-Cr steels with the corresponding American SAE steels. The SAE steels are represented by four numbers and the Continental steels by letters and the percentage of nickel. The Continental ECN and VCN groups are covered by the American steels 4615, 3130, 3240, 5130, 5150, 3312. The analyses of the American steels are given in table Fig. 5. One group of steels, 3130, 5130, and 6130 appears in two Brinell positions on the graph. It was found that materials of two different degrees of hardness had been supplied and machined, but the tool life remained approximately the same. It would be interesting to continue these tests and discover whether there is a definite relation between the Brinell hardness of alloy steels

Test No.	Tool No.	Piece		Speed	Depth	Feed	Gross input HP.	Tool life		Downward cutting force. lbs.	Index 1000 lb. per sq.in.	Remarks
		Mark	dia.	ft/min.	in.	in.		min.	sec.			
1	28235 R	U S-mat.	12"	220	.157	.042	14.6		24	1460	221	Machine stopped Tool badly damaged.
2	28236 R	"	"	225	.157	.042	14.6	5	10	1430	216	dulled and reground.
3/7	28233 S	"	11"	218	.156	.042	14.6	62	31	1460 good 1" dia	220 cuts 8"long	more than an hr; economical life. No chip breaker.
8	28233 S	"	10.44"	155	.313	.042	20.5	1	51	2910	222	Chip breaker .015 x 5/32
9	28233 S	"	10.44"	attempted 200	.313	.042	Not measured.					Mach. stopped; tool damaged.
11	28232 S	"	10.44"	226	.313	.042	24.6	9	45	3400(?)		One hour tool life.
12/15 17/18	"	"	9.816" to 5.4"	212 to 195	.448 to .517	.042 .042	31/ 48	51	31	3630/ 4630	191	Tool shank worn out.
21/24	28236 R	U Cr-Ni	8"	400/820	.040	.0104	6.7/13.4	24	-	330	830	Finish cut tool dulled
25/23	28233 S	"		180	.188	.042	13.3	10	43	1500 to 1700	204	Unmanageable chip. Continuous flowing chip.
29	"	"		180	.372	.042	23.4	-	50	2860	184	
30	28232 S	"	7.126"	180	.375	.042	-	-	20	2860	184	Same long chip.
31/32	28233 S	"		195	.375	.042	24.7	1	45			Special chip breaker; too weak. Tool destroyed.
33/39	28232 S	"	7"	170/190	.375	.042	24	56	35	3150	200	Shank H_B 217 Economical life-tool good. Cut a good chip
40	28236 R	J Cr-Ni	5"	112	.375	.021	15.7	2	45	3050	395	Tool bent.
41/45	28232 S	"	4.94"/4.195"	111/174	.375	.021	16.5/26.8	14	20	330	420	Tool completely destroyed. Shank H_B 197

Fig. 27—New roughing and finishing test of the Research Department.

and tool life and machineability. If such a relation exists the Brinell hardness would constitute a simpler index of machineability than the present machineability index based on force per unit area of chip cross section. This is essential for the rate-fixing department.

The final series of tests was made to determine the effect of coolants (Fig. 30). The material machined was VCN 35 which is very hard (235 Brinell), heat-treated material. First the tool was used dry with a cutting speed of 112ft./min. but the tool life was only a few seconds. When the speed was reduced to 96ft./min. the tool life rose to three minutes, and when the speed was reduced further to 80ft./min. the tool life rose to six minutes. Soap water was then applied at the rate of ·25 galls./min. and the tool life for the three speeds mentioned above rose to 2 minutes, 10 minutes, and 30 minutes respectively. When the coolant supply

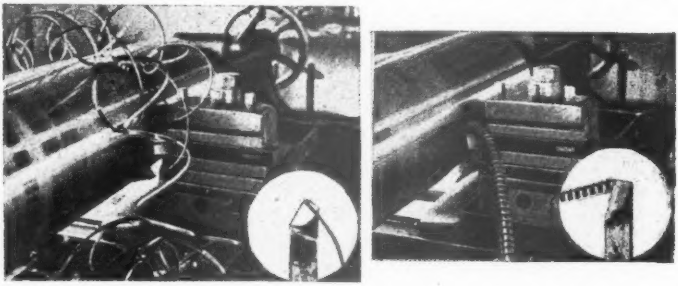


Fig. 28 (a, b)—Swarf removal; dangerous and safe flowing chips.

was increased to 2·5 galls./min. there were further increases of tool life to 4 minutes, 17 minutes, and 43 minutes respectively. Finally, with a coolant supply of 5 galls./min. the tool lasted 4½ minutes, 18 minutes, and 50 minutes. The graph shows that further increases in coolant supply do not have any marked effect upon tool life for with a cutting speed of 80ft./min. the tool life, using 7½ gallons of coolant per minute was 53 minutes, and that using 10 gallons of coolant per minute was 54 minutes. These tests show conclusively that coolant should be used for all roughing cuts and that the optimum quantity of coolant is approximately 5galls./min. The tool used in the above tests was an ordinary 18% tungsten high-speed steel tool. Similar tests are required for the super-rapid steels and cemented carbides.

It is desirable to protect small diameter specimens from deformation and tool points from softening by the use of ample

coolants, but it is essential that the coolant flow shall commence before the cutting action begins. When a cemented carbide commences cutting at, say, 200ft./min. the tool tip is red hot in a few seconds, and if it then comes into contact with cold cutting fluids, cracking will occur.

Another result of these tests is that tool life is greatly increased by the 30% cutting speed reduction from 112ft./min. to 80ft./min.

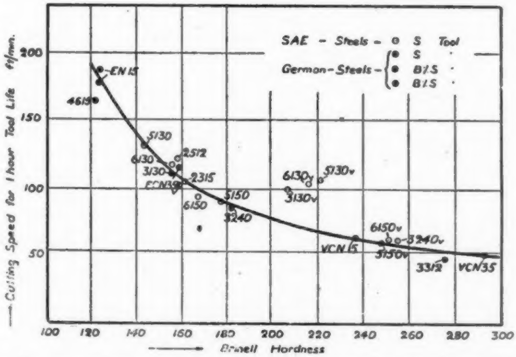


Fig. 29—Relation between Brinell hardness and machineability.

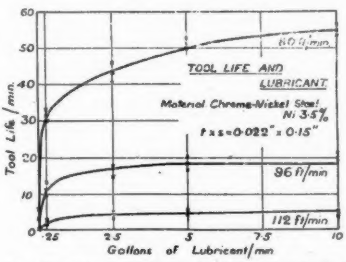


Fig. 30—Relation between tool life and coolant.

It is advisable to wait until reliable information regarding the effect of coolants is available before a comprehensive determination of machineability indices is made with reference to tool angles, cutting speeds, and material machined.

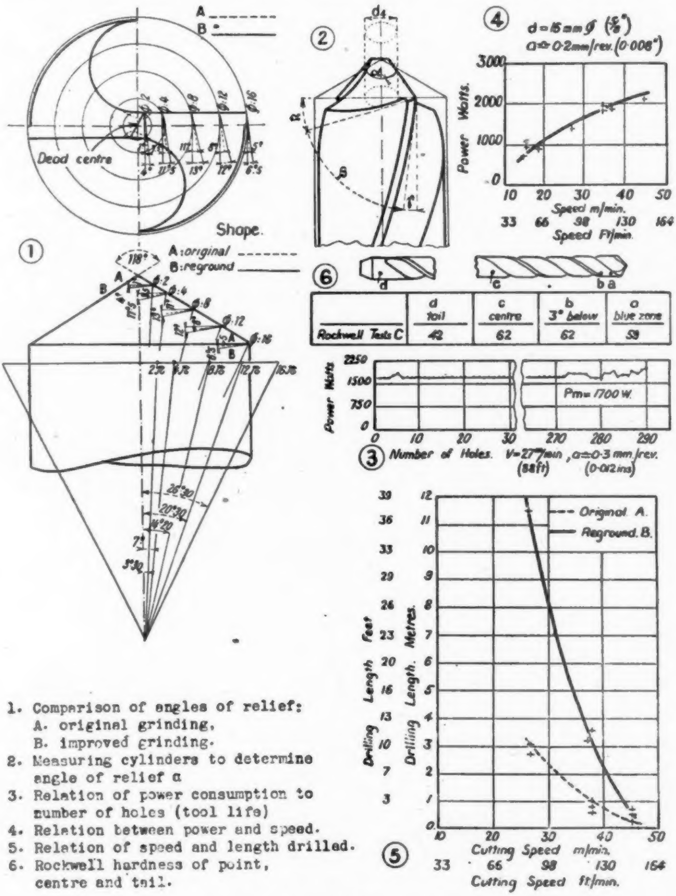
The practical aim of all these tests is to provide reliable data for the rate-fixing department. In general, steel must be machined before it is of practical use, and under conditions such

Machining Group.	Standardised Mark.	Average tensile strength tons/sq. in.	Heat Treatment.	Kind of Tool Steel.	Average max. cutting speed ft./min.	Chip Areas depth × feed.	Special Machining Properties.
I	StC 25·61 StC 35·61	30 32	annealed „	Ordinary high speed steel (18%W)	100 „		short coils ; does not clog.
II	StC 10·61 StC 16·61 EN 15	25 28 35	annealed „ „	Ordinary high speed steel (18%W)	80 „ „		tough clogging; tendency for built-up edge.
III	StC 45·61 StC 60·61 ECN 35	40 50 45	annealed „ „	Ordinary high speed steel (18%W)	65 „ „	from $0{\cdot}08 \times 0{\cdot}04''$ to $0{\cdot}32 \times 0{\cdot}04''$	semi-hard.
IV	VCN 15 VCN 25 VCN 35	45 48 52	toughly heat-treated	Ordinary high speed steel (18%W)	50 40 25		hard and tough.
V	ECN 45 VCN 45	55 60	annealed heat-treated.	Ordinary high steel steel (18%W)	20 18		very tough and very hard.

Fig. 31—Groups of equal machineability for heat-treated mild, semi-hard, nickel, and nickel-chrome steels. (Prescription for rate-fixing department.)

as the present, when speed and production are of utmost importance, it is desirable to have materials which, though tough and hard, can be easily and rapidly machined.

The results of tests made for Continental automobile makers are given in Fig. 31. Thirteen different kinds of steel, ranging from ordinary mild steels to very hard alloy steels, are shown in the table



1. Comparison of angles of relief:
   A. original grinding,
   B. improved grinding.
2. Measuring cylinders to determine angle of relief α
3. Relation of power consumption to number of holes (tool life)
4. Relation between power and speed.
5. Relation of speed and length drilled.
6. Rockwell hardness of point, centre and tail.

Fig. 32—Efficiency of twist drills.

arranged in five groups, distinguished by different cutting speeds. The cutting speed is the most important factor to the rate-fixer. He knows the cutting angles and tool materials which are standardised in his workshops, and if he knows the machineability of the steels his computations will correspond with the actual work which is subsequently carried out in the workshop. Furthermore, when the workman and foreman attempt to carry out the work at the prescribed feeds, speeds, &c., they will find that they can do so without trouble, and that the work is within the capacity

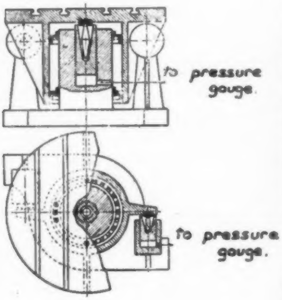


Fig. 33—Drill performance tester for (a) torque, (b) vertical thrust.

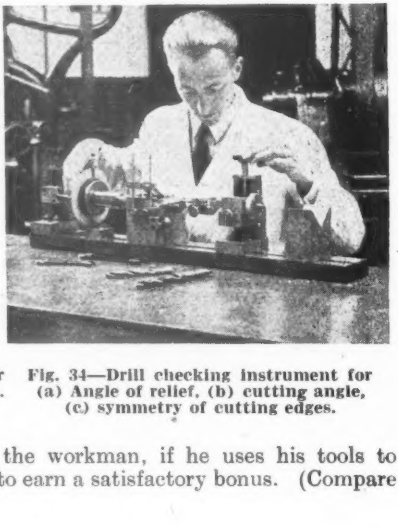


Fig. 34—Drill checking instrument for (a) Angle of relief, (b) cutting angle, (c) symmetry of cutting edges.

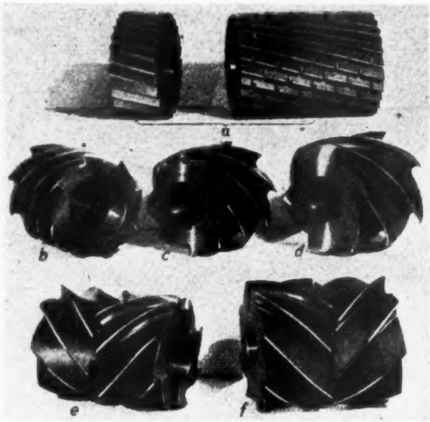
of the machine tool, and the workman, if he uses his tools to their fullest extent, is able to earn a satisfactory bonus. (Compare Figs. 13, 16, and 23.)

Twist Drills

The twist drill is probably the most used tool in the workshop, and as a rule it is used in the hands of comparatively unskilled operators. For this reason the correct grinding of twist drill points is essential if high efficiency is to be maintained (Fig. 32). The twist drill grinder and its operator must be such as to ensure the correct angle of point, which varies for different materials between 90° and 120°, and also the correct angle of relief. Furthermore, it is desirable to select drills with a suitable helix angle of flute. A good twist drill grinder is essential if the tip angles of relief are to be correctly maintained. Most workshops use the same twist drills for cast iron, mild and hard steel, brass, bronze, and light

metals, but for high efficiency it is advisable to have at least three different types of flute, combined with different angles of point and relief, for: (1) cast iron, (2) steel, and (3) soft metals, such as brass, copper, aluminium, elektron, &c.

To determine the machineability index for drilling operations is a problem of great importance. The influence of correct grinding is very great. This fact was clearly shown by a series of twist



(a) Cylindrical Cutter with Small Pitch (axial key)
(b) High Power Cutter with Large Pitch (radial driving slots)
(c) High Power Cutter with Large Pitch (axial key)
(d) Very Coarse Pitch for Light Metals (1000 feet/min. for Aluminium)
(e) Cross Teeth Cutter with Large Pitch for heaviest Cuts - Staggered. (Double-Sided Radial Driving Slots)
(f) Cross Teeth Cutter for Machining Materials of Small and Moderate Resistance.

Fig. 35—Various kinds of modern milling cutters.

drill tests carried out in the Research Department of the University of Brussels in 1938*, when the number of holes drilled without regrinding was increased from 20 to 270 by correcting the drill form, speed, feed, and by the use of coolant (see Fig. 32). This remarkable increase was due primarily to correction of the

* G. Schlesinger, *Cutting Angles of Twist Drills* (*Engineer*, December 9th, 1938, p. 650).

angle of relief. It is interesting to note that the hardness of the drill at the tip was drawn from 62 Rockwell C to 59 Rockwell C (Fig. 32, 6) during the drilling of the first 10 holes; nevertheless, the drill continued to cut satisfactorily for a further 260 holes without any significant increase of power, without spoiling the interior of the hole, and without screaming.

In order to carry out these tests it was necessary to have a drill performance tester (Fig. 33), to measure torque and thrust, and a drill checking instrument (Fig. 34), for testing the form of the drill point, including the angle of relief at various radii.

Milling Cutters

The milling cutter is another tool which has been investigated. Progress in the process of milling is comparatively slow, for

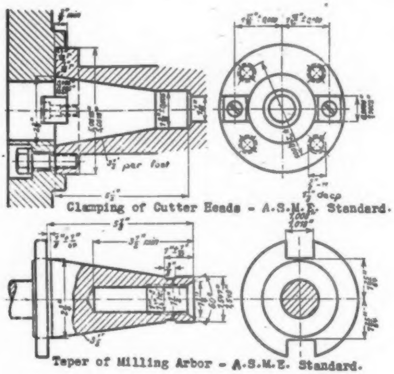
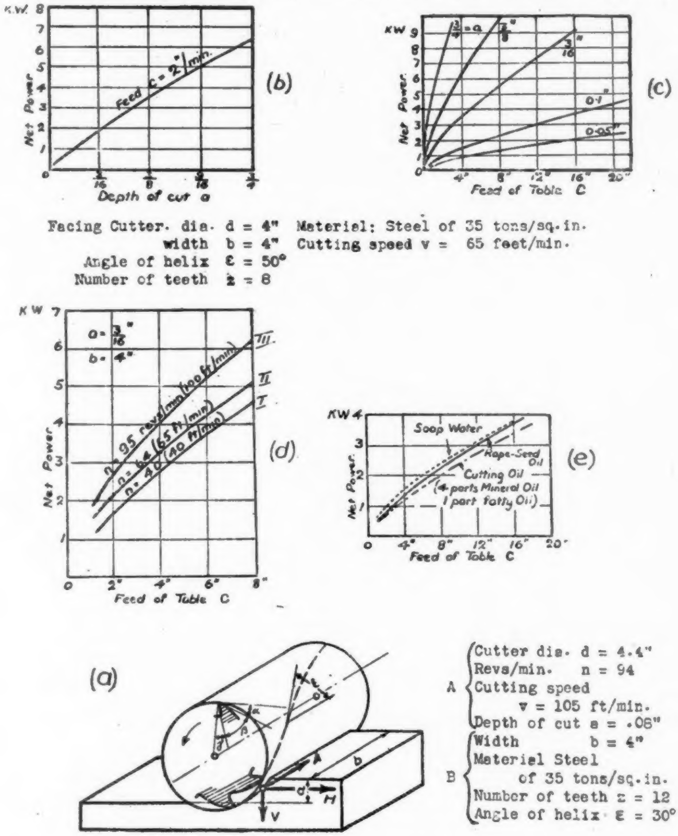


Fig. 36 (a, b)—Taper and driver of the American and British milling arbor and spindle nose.

although milling is usually in charge of skilled foremen, the use of the process is somewhat less than that of other cutting processes such as drilling and turning. The object of investigations on the milling process is to make the fullest possible use of the milling cutters and equipment available. Fig. 35 shows various kinds of high-speed cutters, including an ordinary cylindrical cutter with small pitch, a high-power cutter with large pitch and axial driving key, a high-power cutter with large pitch and cross drive, a very coarse pitch cutter for light metals, cutting up to 1,000ft./min. in the case of aluminium, and two sets of cross teeth cutters for heaviest cuts with double-sided cross driving slots. The milling progress, which is more complicated than

others, is carried out by the cutter driven by an arbor which is held in the machine spindle.

The drive of the milling arbor and its fastening in the main spindle are greatly improved in the American standard type of



(a) Cutting action of milling cutter.
(b) Relation of power to depth of cut for constant feed.
(c) Relation of power to feed for various depths of cut.
(d) " " " " " " " speeds.
(e) " " " " " using various lubricants

Fig. 37 (a to e)—Forces acting at the tooth of the milling cutter; relation between power and depth and power and feed.

spindle nose (Figs. 36a, 36b), accepted by the B.S.I. Specification No. 739—1937. The three fundamental requirements are: (1) centring, (2) clamping, (3) driving. Centring is effected by the rear cylinder and by the steep taper, which does not seize. Clamping is effected by the rod and internal thread, and driving is effected by two dogs situated at the largest diameter of the flange. It is unfortunate that this marked improvement of the cutter drive is restricted to the parts within the spindle nose, and does not include arbor diameters and improved driving methods for the cutter itself. The transfer of the torque to the milling cutter is as unsatisfactory as it was at the time of the invention of the milling machine in 1878, due to the small diameter of arbor weakened by a single key groove. The load-carrying part of the milling arbor still remains weak, and it is this weak part which determines the work done by the machine, both regarding quantity

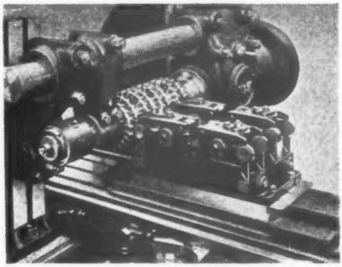


Fig. 38—Gang of eight heavy cutter heads on standard arbor.

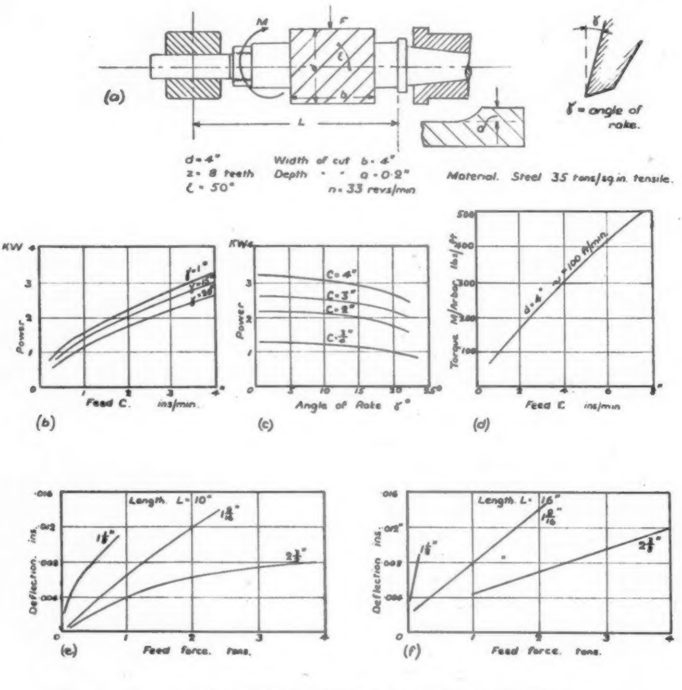
of chips and quality of surface. If a strong milling machine makes noise, and refuses to take a reasonable amount of chips with a well-ground cutter, it is always the fault of the weak milling arbor. The drive to the cutter is effected by an axial key or by radial driving dogs. The cutter arbor, which is often quite long, is supported by an overhanging arm. Three forces acting upon the cutter during the milling process are measured (Fig. 37a) in three mutually perpendicular directions—horizontal, vertical, and axial. Other factors which must be noted are width and depth of cut, circumferential speed of cutter, angle of helix, number of teeth, the kind of material being machined, and particulars of any coolant or lubricant used. In Fig. 37a is shown the angle of rake (γ), which is the angle between the radius of the cutter and the breast of the tooth. The four diagrams (Figs. 37b–e) show the relation between power and depth of cut, power and feed of table,

and also the influence of speed and of the use of a coolant—in this case soap-water. From Fig. 38 it is clear that the forces involved may be very great (3 to 5 tons). This figure refers to a gang of eight cutter heads of 8in. diameter on the same arbor of $1\frac{1}{2}$in. diameter, all cutting at the same time, but with the very small feed of less than $\frac{3}{8}$in. per minute. In spite of this low feed the gain both in time and interchangeability of components is sufficient to offset the cost of such expensive tools.

Fig. 39a–f show the effect of the action of the milling cutter on the arbor itself for a given cutter: diameter 4in., 8 teeth, 50° angle of helix, 4in. wide, cutting at 33 r.p.m., ·2in. deep, on steel 35 tons/sq. in. tensile strength. The diagrams show the influence of different angles of rake (γ) on the power consumed for a given feed, and also the relation between feed and angle of rake. Another diagram shows the relation of torque to feed under given cutting conditions. The two diagrams (e and f) at the bottom of Fig. 39 show the deflections caused by forces from 100lbs. up to 4 tons on arbors having three different diameters, $1\frac{1}{8}$in., $1\frac{9}{16}$in., and $2\frac{3}{8}$in., and two lengths 10in. and 16in. From this information we conclude that it is desirable to have the largest diameter arbor possible. This requires a large hole in the cutter, which, in turn, requires larger diameter cutters. It is well known that for economical milling the smallest diameter cutter is most desirable, so that we are faced with the problems of deciding the optimum diameter of arbor to give sufficient rigidity and at the same time economical cutting. When these optimum values corresponding to various cutter diameters have been decided, standardisation should follow.

The influence of the method of driving the cutter upon the rate of metal removal is shown in Fig. 40. The cutters (*a*) and (*b*) differ from 7 to 8 teeth, and the cutters (*b*) and (*c*) from 8 to 10 teeth, but the diameters of the arbors are $1\frac{9}{16}$in. and $2\frac{3}{8}$in. respectively, and the method of driving is changed from the axial drive with one key, which gives an eccentric torque and a single bending force, to the concentric double-sided drive, which eliminates single bending forces. The gain in metal removal is clearly shown by the fact that with a 4 h.p. machine the feed on cast iron was increased from $4\frac{1}{2}$in. per minute to $7\frac{1}{2}$in. per minute, which represents a 65% increase, and with a 3 h.p. milling machine the feed on Ni-Cr steel was increased from 3·5in. per minute to 6·6in. per minute, which represents a gain of 90%. Thus it is clear that by replacing an incorrect cutter drive by a correct cutter drive the output is almost doubled. Furthermore, the surfaces obtained with correct cutter drives are much smoother than those obtained with incorrect cutter drives. This improve-

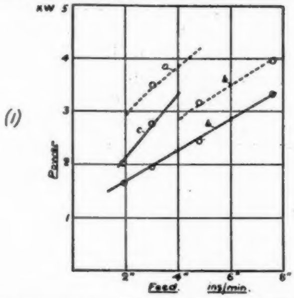
ment is largely due to the fact that with correct cutter drives twisting of the cutter teeth is practically eliminated, and that the action of the drive is located at a greater radius, so that chatter is reduced and the cutting action is smooth and practically vibrationless. Before the angles for milling cutters can be satisfactorily standardised this problem of cutter drives must be solved and uniform practice adopted (Fig. 41). In this table six classes of material are given with the corresponding clearance angles and rake angles. In practice the correct angles can only be obtained in the case of inserted blade cutters when each blade can be treated



(a): Working arrangement and Dimensions of Cutter.
(b): Relation of power to feed C if breast rake γ is variable
(c): Relation of power to γ if feed C is variable.
(d) Relation of torque to feed if circumferential speed remains constant.
deflection of arbors for
(e) 3 different diameters-length of arbor 10"
(f) 3 different diameters-length of arbor 16"

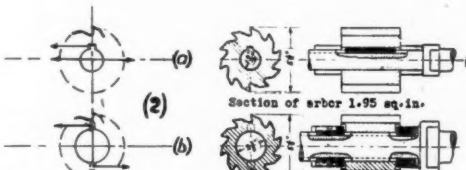
Fig. 39—Relation between diameter and length of arbor and deflection.

as a single point cutting tool. In such cases top rake, side rake, and clearance can be adapted to suit the material being machined. In addition it is possible, if desired, to replace high-speed blades by cemented carbide-tipped blades, which permit a considerable



Graph	Material	Hardness Brinell	Cut Width in.	Cut Depth in.	Feed in.	Cutting speed ft/min.	Dia. of cutter in.	Key	Teeth	Angle of helix	Power	Ratio
a	Cast iron	163	3	[illegible]	4.5	50	3	axial	7	20	4	1.-
b	" "	"	"	"	7.5	"	"	across	8	25	"	1.65
b	VCN 35 h	288	[illegible]	[illegible]	3.5	50	3	axial	8	25	3	1.-
c	" "	"	"	"	6.6	"	"	across	10	20	3	1.9

Influence of Cutter Drive to the Power-Input of the Milling-Machine.



Section of arbor 1.95 sq.in.

Section of arbor 4.45 sq.in.

(a) eccentric (one sided): bending action.
(b) pure torque

(3)

Length of Arbor	Diameter of Bore	Mean Pressure	Deflection on Middle of Arbor
20	1 9/16	1 ton	.00150"
20	[illegible]	1 ton	.00033"

Correct and incorrect cutter drives.

(1) Relation of power to feed using (a) axial key, (b) cross drive.

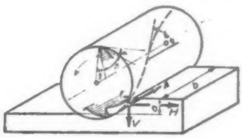
(2) (a) eccentric force at one-sided key on arbor
(b) pure torque transmitted by 2 cross drivers on both sides of cutter.

(3) Influence of increase of diameter on deflection of arbor.

Fig. 40—Correct and incorrect cutter drives.

increase in speed, which, incidentally, is accompanied by a decrease in cutting forces.

Returning finally to the first illustration (Fig. 1), we note that force × speed = power. This relation is valid for the milling machine, so that by doubling the speed we are able to decrease the force to half its original value, and thus diminish the deflection of the arbor and produce a mirror-like milled surface. Great care must be taken to avoid vibration at high speed, and this involves accurate balancing and accurate location of every single groove and blade. The required accuracy, however, is well within the economic limits of production, and yields its due reward in increased output.



Material	Clearance α	Rake angle γ	
		High efficiency	Ordinary use
Hard brass or bronze, hard cast iron	5°	0°	0 - 5°
Steel castings and steel above 50 tons/sq.in., cast iron, red-brass, bronze brass	5°	8°	0 - 5°
Steel castings and steel of 35 to 50 tons/sq.in. soft brass	5°	12°	0 - 5°
Steel castings and steel of 22 to 35 tons/sq.in.	5°	15°	0 - 5°
Tough and soft bronze, very soft steel	8°	15 to 20°	0 - 5°
White and light metals	8°	30°	0 - 5°

Fig. 41—Proposal to co-ordinate the cutting angles to the various materials.

The Research Department is indebted to Mr. Percival Smith, Technical Director of the United Steel Corporation (Sheffield), for the permanent loan of the small cutting tool dynamometer (Fig. 20), which was made useful by developing the unsensitive electrical measuring box for this instrument, with the help of Messrs. Tait/Shaw (London). Further, to Messrs. John Lang (Johnstone) for the gift of the mechanical part of the big dynamometer, and to Metropolitan Vickers (Manchester) for the permanent loan of the electrical part of it (Fig. 21). Finally, we have to thank for the gift of the drill performance tester and the point calibrating instrument (Figs. 33 and 34) as gifts of Messrs. Thos. Firth and John Brown Ltd. (Sheffield), by the kind influence of Mr. J. H. Barber (Technical Director).

Research Department: Production Engineering Abstracts

(Edited by the Director of Research)

NOTE.—*The addresses of the publications referred to in these abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough.*

ANNEALING, CASE-HARDENING, TEMPERING.

Heat Treatment: Dry Cyaniding or Nitro-cementation, by D. McPherson. (*Machine Shop Magazine, January, 1942, Vol. 3, No. 1, p. 98, 4 figs.*)

Dry cyaniding or nitro cementation are terms which have been coined to describe a process which in principle is a combination of two separate processes, namely, carburising and nitriding. The carburising is performed with gaseous media, i.e., hydrocarbons suitably diluted with neutral or slightly carburising gases, and the nitriding is made concurrent with the gaseous cementation. It is not essential to employ diluted hydrocarbons in place of the older method of compound or pack carburising. Ammonia may under carefully controlled conditions be introduced into a pack carburising container and produce a somewhat similar effect. It is, however, more convenient to introduce nitrogeneous gases into a gaseous atmosphere and easier to ensure adequate distribution. The processes under review in this article are all carried out on the principle of introducing ammonia or other suitable nitrogeneous gas into a furnace atmosphere of diluted hydrocarbon such as methane, butane, or propane. The fundamental advantage of nitro-carburising is that where gas carburising equipment is available gas cyaniding may be performed with the same equipment. Nitro-carburising is a cleaner and more hygienic process and, from the operator's point of view, is free from discomfort and the danger of explosions; danger from the poisonous nature of the cyanide salts is obviated also. No extensive cost comparisons are available at the time of writing, but preliminary tests on continuous nitro-carburising furnaces show that costs are comparative with a slight but definite leaning towards nitro-carburising as the cheaper process.

Heat Treatment of Molybdenum High-speed Steels. (*Machinery, January 29, 1942, Vol. 60, No. 1529, p. 33.*)

Increasing use is being made of molybdenum high-speed steels in place of conventional tungsten steels that are now difficult to obtain. Many steel users, however, are unfamiliar with the proper heat-treating procedures for molybdenum steels. A special committee of the U.S.A. Office of Production Management has prepared certain recommendations intended to prevent difficulties that might arise from using incorrect methods or wrong equipment. Molybdenum steels can be forged like the tungsten type, but at a slightly lower temperature. The general method of hardening molybdenum high-speed steels resembles that used for 18-4-1 (W-Cr-Va) steels, but the hardening temperatures are lower and more precautions must be taken to avoid decarburisation. To reduce the possibility of breakage and undue distortion of intricately shaped tools it is advisable to quench in a molten bath at approximately 1,100°F. Borax may be applied by sprinkling it lightly over the steel when the latter is heated to a low temperature of 1,200 to 1,400°F. Small tools

heated as described in the foregoing may be rolled in a box of borax. Special protective coatings or paints, when properly applied, have been found extremely useful.

Heat Treatment of Molybdenum High-speed Steels. (*Mechanical World, January 30, 1942, Vol. CXI, No. 2874, p. 95.*)

American data used officially in replacing tungsten material. Annealing and hardening. Quenching; coatings; salt-bath methods; Molybdenum high-speed steels will take all the special surface treatments, including nitriding, when immersed in molten cyanide, that are applied to tungsten high-speed steels for certain applications. Controlled atmosphere.

Minimising Distortion, by J. G. Magrath. (*The Machinist, January 24, 1942, Vol. 85, No. 44, p. 1036, 6 figs.*)

For many flame-hardening jobs distortion is negligible; for others it can be controlled by the expedients described. The amount of distortion encountered in flame hardening is generally well within manufacturing tolerances. When distortion does occur it can be reduced by a stress relief draw (tempering). While generally recommended, the drawing (tempering) operation is not always necessary, since by carefully controlling the quantity and application of the quenching medium or delaying its application, the hardening treatment may be made self-drawing. Where parts are machined only, followed by flame-hardening and then finish-ground, care must be taken not to set up grinding stresses. Such may occur, resulting in surface checks, when too severe a grinding procedure is employed. Slow, fine, and preferably wet grinding should be employed.

BELTS, ROPES.

A Formula for Belt Lengths, by A. B. Cox. (*The Machinist, January 3, 1942, Vol. 85, No. 41, p. 935, 1 fig.*)

This formula can be used for calculating accurately the length of plain leather belts, V-belts, rope drives and chains. It is as accurate as the measurements of pitch diameter and centre distance.

COMBUSTION, FURNACE.

Furnaces for Production Heat Treating, by Rupert Legrand. (*The Machinist, January 24, 1942, Vol. 85, No. 44, p. 1027, 8 figs.*)

Material handling has been added to the functions of many modern furnaces; they are often a part of the production line. Mass-production heat-treating on a tonnage basis is the field of the roller-hearth furnace. The roller-hearth furnace is limited in charging width and unit loading as compared to the walking-beam type. Modern roller-hearth furnaces frequently involve the use of protective atmospheres. Roller-hearth furnaces are intended for operation continuously on a three-shift basis for a month or more before being shut down for inspection or repair. Operating labour is comparatively small per unit of output, but depends in large measure upon the adequacy of charging and unloading equipment. Pusher furnaces are widely used in production heat-treating of (1) work that cannot be conveyed suitably through walking-beam or roller-hearth furnaces, (2) work in which unit loadings and dimensions are not suitable for belt furnaces, and (3) for plants in which a wide variety of parts are best handled by the tray system. For furnaces intended for annealing large tonnages of castings or other products the recuperative principle is employed. Cold work enters the furnace on one path, is pushed to the rear of the furnace, and there transferred mechanically to the return patch. Cold work is thus preheated by heat given up by annealed work. About 30% of the heat required in the annealing process is saved by the use of the recuperative principle.


BRITISH CRAFTSMEN
with
PRECISION PLANT
make
PRECISION TOOLS
Fine toolmaking
A TYPICAL MILLING FIXTURE

EMPLOYEES, WORKMEN, APPRENTICES.

The Crisis of Man-power. (*Labour Management, January, 1942, Vol. XXIV, No. 256, p. 3.*)

(1) National Service (No. 2) Act, 1941. The position of men. The position of women. Registration of boys and girls. (2) The transfer of women to vital war work. Mobilising woman power. The transfer of mobile women. The use of directions.

Apprentice School. (*Industrial Welfare and Personnel Management, January, 1942, Vol. XXIV, No. 278, p.5.*)

Training scheme for boys in a medium sized engineering works. Selection of apprentices. Syllabus. Progress. Welfare and working conditions.

FOUNDRY.

The Production of Machine Tool Castings. (*Machinery, January 1, 1942, Vol. 59, No. 1525, p. 381, 12 figs.*)

Modern Foundries, Limited, was incorporated in 1932 as a subsidiary company of the well-known machine tool making firm of William Asquith, Limited. The main foundry has recently been reorganised throughout and equipped with the latest foundry plant and labour-saving devices with a view to facilitating the economical and rapid production of machine tool castings for not only the parent company but also for other customers. More recently there has been added a new two-storey building adjacent to the main foundry, which houses the works' offices, laboratories, pattern shop, pattern stores, brass and bronze foundry, and moulders' washing and locker accommodation. A description of the layout of these works and of the methods used are given.

Cast Iron Handbook. (*British Standards Institution, "Data on Cast Iron," British Standard 991, November, 1941.*)

The booklet is prepared by the Technical Advisory Panel to the Director for Iron Castings, The Iron and Steel Control, Ministry of Supply, in collaboration with the British Cast Iron Research Association and the Institute of British Foundrymen. It is issued for the guidance of engineers and designers in the Service departments, engineering institutions, and others concerned with the use of cast iron in engineering practice. Concise data on the nature of cast iron; classification of the types of cast iron now available. Detailed consideration of pearlitic-grey cast iron. Mechanical properties. Heat-treatment procedure. Properties developed by quenching and tempering. Condensed summary of the properties of martensitic cast irons. Properties representative of austenitic irons. Properties of malleable cast irons of the white-heart and black-heart types.

(*Supplied by "The Nickel Bulletin."*)

MACHINE ELEMENTS.

Slackness of Ball Bearings, by H. Zetterstrom. (*Mechanical World, January 2, 1942, CXI, No. 2870, p. 4, 3 figs.*)

Some questions on the matter as it is encountered in single row ball bearings, together with the answers, are given. These include: What is meant by diametric slackness; what is meant by axial or lateral slackness; the theoretical connection between the diametric and the axial slackness; the object of the diametric slackness or running clearance; there is no way of measuring accurately the diametric slackness in an assembled bearing. It is of a very low order of magnitude. The influence of gauging pressure on axial slackness measurement and the various methods used in determining the diametric slackness are also mentioned. In pursuance of a policy of progressively increasing the efficiency of ball bearings the

manufacturers have given these slackness problems much attention, and supply bearings with standard diametric slacknesses of different magnitude most suitable for practically any application.

Split-ring Friction Clutches, by R. Waring-Brown. (*Mechanical World, January 9, 1942, Vol. CXI, No. 2871, p. 23, 8 figs.*)

The advantages attending the use of frictional clutches are manifest in that they eliminate the necessity for clutches on lineshafts or countershafts and obviate the use of tight and loose pulleys. Further, the introduction of a friction clutch directly on the machine is not limited to belt drives but is equally applicable to gear or chain transmissions. The article deals with the essential considerations affecting the design of split-ring clutches, wedge-operated split-ring clutches, lever-operated split-ring clutches, and toggle-operated split-ring clutches. In all the clutches of the type herein reviewed the split friction ring is highly important. If the ring lacks flexibility it will undoubtedly institute uneven distribution of the pressure at the friction surfaces. If the split-ring is too flexible it may be expanded to some extent by centrifugal force and cause premature engagement, or cause difficulty in disengagement at high speeds. The diameter of the split-ring should be from 15 to 35 thousandths of an inch smaller than the shell diameter upon which it is to operate, but in machining it should be expanded to the size of the shell; this will ensure a proper fit and equalised pressures.

Hand Chain-wheels, by G. H. Pearson. (*Mechanical World, January 23, 1942, Vol. CXI, No. 2873, p. 67, 12 figs.*)

Quite a variety of mechanical appliances which call for remote operation rely on manual operation through the agency of ordinary link chain and chain-wheel mechanism. Two sizes of chain in common use, and suitable for hand chain-wheels; wheel and rim details of a chain-wheel. Chain-wheel rim details and proportions. Hub and arms. Shrouded wheel type, eliminating danger of the chain jumping the rim. Chain guides. Length of chain.

MACHINING, MACHINE TOOLS.

Honing Tools and Related Equipment, by L. S. Martz. (*Mechanical Engineering, U.S.A., December, 1941, Vol. 63, No. 12, p. 865, 9 figs.*)

1—Functions of the honing process. 2—Some major requirements of surface generation: (a) Surface quality; (b) plastic deformation; (c) stock removal by shear. 3—Fundamental principles of abrading actuation: (a) Abrasive structure; (b) force application; (c) direction of motion; (d) rate of motion or speed. Uniform removal of stock by honing. Comparison of abrading area contact and speed. Characteristics of honing-tool action. Pathway of honing stick. 4—Unique controls used in honing equipment: (a) Tool construction; (b) actuating controls.

Internal Grinding, by W. Boneham. (*Machinery, January 29, 1942, Vol. 60, No. 1529, p. 33, 2 figs.*)

The usual recommendations of a surface speed of 5,000ft. per minute require very high spindle speeds—for example, a $\frac{3}{8}$in. diameter wheel requires approximately 50,000 r.p.m., and whilst such speeds are not impossible, a very light grinding spindle is required, with consequent loss of power and rigidity, together with increased wear and tear, an important factor in continuous production. A table is given showing grinding wheel sizes, quill sizes, and maximum quill lengths to be used as a basis from which to work. It has been found very satisfactory for internally grinding hardened steel on production internal grinders, but is not intended to apply to tool post grinding. For grinding small

bores up to $\frac{3}{4}$in. a carborundum J grade wheel is suggested, working at a fairly low surface speed; this has been found more satisfactory than using high speeds and a softer wheel. Mounted wheels should be used on bore sizes below $\frac{3}{16}$in. diameter only, because not only are they more expensive, but the wheel easily breaks away from the shank, entailing frequent replacements. Work speeds between 100ft. and 150ft. per minute will usually be found the most satisfactory. It must be remembered that when making alterations to the speeds to suit individual work: (1) reducing the grinding wheel speed is equivalent to using a softer wheel; (2) increasing the work speed is equivalent to using a softer wheel; (3) the harder the material, the softer the wheel required; (4) the larger or closer the grinding wheel diameter is to the bore being ground, the softer the wheel required; (5) the higher the traverse speed, the harder the wheel required; (6) an interrupted bore, such as a keyway, requires a harder wheel. When making alterations to speeds to suit individual work it is preferable to alter the work and traverse speeds rather than lower the spindle speed, and, in any case, is usually more convenient. There are three types of grinding spindles normally used: (1) the removable quill type; (2) the solid quill type; (3) the sleeve type. It is false economy to expect one size of grinding spindle to cover a wide variety of work, except for toolroom operations. By using the correct size spindle and quill for a particular job, an increase in production of as much as 50% can be obtained. Where possible, it is best to use a spindle running at just a few thousand revolutions below its maximum speed.

MANUFACTURING METHODS.

Some Improvements to Facilitate Cutting Acme Threads. (*Machinery, January 15, 1942, Vol. 59, No. 1527, p. 462, 15 figs.*)

The Acme thread takes its bearing under pressure on one flank of the thread only; and since the thread is made with a basic major and minor diameter the tolerance for obtaining the fit can be secured by placing it all on the flanks or side angles of the thread. It should be remembered that the clearance between the root and crest of an Acme thread is rather liberal since it amounts to 0·010 inch. Therefore, to obtain a free fit, if the tolerance is all on the side angle, a more practical form of thread is obtained, in that the depth of engagement will always be constant and the working tolerance will be limited merely to the side angles. One of the most expensive difficulties in cutting Acme threads with a die is due to the fact that designers seldom allow enough space for the imperfect threads produced by a chaser throat. For single Acme threads, cut in steel, the chaser throat angle should not be more than 12° to distribute the cut properly. It appears to be a common fault to limit the amount of relief or clearance at the end of the thread to the pitch of the thread, or in some cases to even less than the pitch. This is an expensive and impractical method when the threads are cut with the die-head.

Progress of Research and Control (Production of Aluminium Powder). (*Light Metals, December, 1941, Vol. 4, No. 47, p. 242.*)

Describes the rolling method for production of Al powder. References to patent literature.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Machining Shell with Carbide Tools, by M. F. Judkins. (*Mechanical Engineering, U.S.A., December, 1941, Vol. 63, p. 859, No. 12.*)

Comparison of world war with to-day's production. Speeds and feeds for machining shell forging. Getting best results from carbide-tipped tools.

Shell Cases Made in Canada. (*The Machinist, January 31, 1942, Vol. 85, No. 45, p. 1052, 22 figs.*)

The Frankfort Arsenal has worked out methods in great detail for the production of 75mm. shell cases. The layout of a unit department to produce approximately 600 cartridge cases per hour. Operations sheet.

Canada: Arsenal of the Empire. (*The Machinist, January 10, 1942, Vol. 85, No. 42, p. 967, 43 figs.*)

Details of the processes used in some Canadian factories to build munitions for Britain.

Shell forging by the upset method.

The Bristol Hercules—Part I, by J. A. Coates. (*Aircraft Production, February, 1942, Vol. IV, No. 40, p. 176, 34 figs.*)

This series of articles deals with production processes in the manufacturing of the Bristol Hercules radial sleeve-valve engine at one of the shadow factories acting on behalf of the Ministry of Aircraft Production. Years of patient research and experimental work by the Bristol Aeroplane Co. were necessary before the engine reached its present high state of efficiency, and to-day it is the power unit of a number of famous military aircraft. Production has been brought to a state of perfection by the coordinated effort of the Bristol Aeroplane Co. and the Shadow Factory engineers. Skilful planning has overcome the many difficulties arising from the necessary employment of a large percentage of female labour.

The Production of Heat-treated Light Alloy Castings. (*Light Metals, December, 1941, Vol. 4, No. 47, p. 240.*)

Before age-hardenable Al and Mg alloys are produced on a large scale to D.T.D. and other specifications, a certain amount of preliminary investigation is advisable to determine the optimum heat-treatment conditions within the ranges allowed by the specifications. Once these conditions have been established accurate control is necessary during full-scale production. Author discusses practical aspects.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Copper base Castings, by J. W. Bolton. (*Metals and Alloys, October, 1941, Vol. 14, No. 4, p. 447.*)

A short note on melting and pouring, dealing specially with furnace atmospheres and temperature control, written with a view to increasing production rates.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Planning Machining Operations for Unskilled Labour. (*Machine-Tool Review, September-December, 1941, Vol. 29, No. 179, p. 81, 10 figs.*)

Examples: (1) Mitre gear blank previously machined in two operations by a skilled man and now done in three operations by a woman. (2) Cluster gear blank. Skilled man—four operations. Woman operator—seven operations. (3) Clutch friction ring, showing faces to be machined. Fixture which enabled a woman operator to machine six rings at once on a milling machine. (4) Sole plate for a square turret. Previously machined by a skilled man on a vertical milling machine. Special fixture for machining the vees on the sole plate. A woman operator is doing both operations.

Designing for Machineability, by J. E. Thompson. (*Aircraft Engineering, January, 1942, Vol. XIV, No. 155, p. 25, 30 figs.*)

Milling. Milling cutters. Design practice. Comparisons of: incorrect and correct; shoulder milling; straddle milling; spotface; direction of feed; face milling. End milling with a vertical miller. Keyways.

Cogent

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MATERIALS, MATERIAL TESTING.

Conservation and Reclamation of Materials. (*Mechanical Engineering, U.S.A., January, 1942, Vol. 64, No. 1, p. 25, 11 figs.*)

CASE I: RECLAIMING AND USING SCRAP MATERIALS, BY W. W. FINLAY. —A very important consideration is the handling of machine lubricating oils, cutting oils and coolants, washing solvents, degreasing fluid (trichloroethylene), honing compounds and grinding coolants, engine lubricating oil. In addition, there is the obvious problem of handling large quantities of cuttings and chips with segregation of the materials for eventual use or disposal in the pure form, so far as is practical. The disposal problem is largely one of intelligent segregation.

CASE II: EXAMPLES OF CONSERVATION AND RECLAMATION, BY W. L. H. DOYLE.—(1) Mild-steel turnings are loaded into freight cars. (2) Nickel-steel turnings are given chemical spot-check test. (3) Usable life of grinding wheels has been increased four times. (4) Iron borings are briquetted. (5) Templates made from sheet-metal scrap; chips are baled for cupola charging. Changes in cutter design have extended useful life. A replacement sprocket can be welded to the still serviceable hub.

CASE III: REDESIGN, SUBSTITUTION, SIMPLIFICATION, AND STANDARDISATION, BY D. R. KELLOGG.—Used by the Westinghouse Electric and Manufacturing Company. Ranges and cabinets; changes at Cleveland plant.

CASE IV: MATERIAL SUBSTITUTIONS, BY F. J. ALLEN.—Details of finned refrigeration coil for which material substitutions were made.

Powder Metallurgy Processes, by W. D. Jones. (*Mechanical World, January 30, 1942, Vol. CXI, No. 2874, p. 91, 1 fig.*)

Porous bronzes; sintering; moulding to finished sizes. The familiar hard-metal carbide tool of the type of Widia, Ardoloy, Cutanit, Tecometal, &c., is made entirely by powder metallurgy. The composition of the Alnico magnets is somewhat variable according to the grade and manufacture, but runs in general 9% to 13% aluminium, 17% to 24% nickel, 5% to 12% cobalt, sometimes copper, and the remainder iron. Refractory metals and tungsten, molybdenum, tantalum, platinum, &c. Iron parts. Typical of such parts are a tappet from a washing machine, a part from a push-button radio tuner, a part in the dictating machine, a non-squeaking part from an automobile window winder and an automobile oil-pump gearwheel. In hot pressing of moulding powders pressure is given to the powder while it is cold, and the cold compressed compact is heated up and then pressed again while it is hot.

The Routine Quantitative Spectographic Analysis of Magnesium Alloys. (*F. A. Fox and J. Nelson, J. Soc. Chem. and Ind., Vol. 60, No. 11, November, 1941, p. 278.*)

An account is given of the development of the application of the spectrograph to the quantitative analysis of magnesium alloys. Details of a routine method of spectrographic analysis by the "comparison sample" method are given, and it is shown that for constituents in the range of 0·1% to 3% an accuracy of ±4·5% of the content can be obtained. Aluminium, when present in amounts greater than 4%, cannot be estimated by the method indicated with a mean accuracy greater than ±7%.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

Magnesium from the Sea, by D. H. Killefer. (*News Edit., Amer. Chem. Soc.), November 10, 1941, Vol. 19, No. 21, p. 1189.*)

Notes on the new Mg plant of the Dow Chemical Co. at Freeport, Texas, and on the steps for production of Mg from sea-water. At present, the total Dow output is 36,000,0000lbs. Mg annually. Other plants planned (list includes four more Dow plants and two others) will raise output to 400,000,000lbs.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

Bureau of Standards Researches on the Mechanical Properties of Alloys at Low Temperatures. (*Light Metals, U.S.A., Vol. 4, No. 46, November, 1941, p. 212.*)

A number of aluminium and magnesium alloys were tested over the temperature range +20° C. to −80° C., the following factors receiving special attention: ultimate tensile, yield point, elongation, reduction in area, impact resistance, hardness.

The effect of long period exposure to −80° C. before testing the specimen at room temperature was also investigated.

In the case of the aluminium alloys the effect of the temperature range is a consistent but small increase in all the factors enumerated above. Previous exposure to −80° C. produced, however, scarcely any effect on the values obtained subsequently at 20° C. For the magnesium alloys the increase accompanying a lowering temperature is slightly more marked, and there is evidence of an appreciable effect of prior exposure to cold for certain of the wrought magnesium alloys.

There is also some evidence that high-speed machining operations on automatics are favourably affected by cold (either by flooding with strongly cooled cutting fluid or by refrigerating the material prior to machining).

The effect of cold on fatigue, corrosion, and general wear still requires further experimental investigation.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

Alternate Steels for Emergency Use. (*The Machinist, January 24, 1942, Vol. 85, No. 44, p. 1039.*)

This article discusses the working of possible alternates for steels most restricted by government priorities, that is, those with low percentages of the alloying elements most needed in the production of items essential to the National Defence programme. Specially treated steels, as by the Granial process, the medium-manganese and straight-molybdenum types are the most hopeful alternates. The chromium, chromium-molybdenum, and chromium-vanadium steels have excellent properties, but their availability may be clouded by the possibility of future shortages. The steels discussed in this article may be divided into three general classes: (1) The oil or water-hardening steels containing from about 0·25% to 0·55% carbon, which are used where deep-hardening characteristics are desired. (2) The carburising steels, usually containing less than 0·25% carbon, which are used where a very hard-wearing surface is to be obtained accompanied by good toughness and shock resistance in the core of the finished part. (3) The high-speed and hot-work steels, which in the majority of cases prior to priority regulations were high in tungsten, but now are being replaced by molybdenum or molybdenum-tungsten steels of equivalent properties.

In considering the various types of molybdenum high-speed steel two general classifications must be made. The first is based upon the component alloying elements, tungsten, molybdenum, vanadium and cobalt. The second general classification is based upon the carbon range of any given alloyed steel. The molybdenum high-speed steels can be forged

like the tungsten type but at a slightly lower temperature. These steels, like other high-speed steels, should be annealed after forging and before hardening or when rehardening is required. In general, the method of hardening the molybdenum high-speed steels resembles the practice with 18-4-1 but the temperatures are lower. Tools may be quenched in oil, air, or molten bath. Data on machining the steels discussed in this article will be found in "The Working of SAE Nickel Alloy Steels" (AM-Vol. 83, page 865), and "The Working of High-speed Steels" (AM-Vol. 84, page 93). Cutting tool angles, as well as speeds and feeds for machining, drilling, tapping, threading are given. Recommended coolants for all types of machine work are listed, as are types of grinding wheels and speeds.

Determination of Molybdenum in Alloy Steels, by G. M. Poole. ("*Simplified Molybdenum Determination,*" *Iron Age, 1941, Vol. 148, October 9, pages 62 and 164.*)

The procedure described is a modification of the James method (Ind. and Eng. Chem., Anal. Edn., 1932, Vol. 4, p. 89), using the Cenco-Sheard-Sandford photelometer.

(*Supplied by "The Nickel Bulletin."*)

Stainless Steel (Effect of Cold Working), by J. M. Bandal. (*Iron Age, October 9, 1941, Vol. 148, No. 15, p. 45.*)

An investigation of the effect of various degrees of cold working on the mechanical properties of 18-8 and 17-7 Cr-Ni steel strip. 18-8-2 and 18-5-5 Cr-Mn-Ni steels are also being investigated, and so far results appear to be promising. The cylinder test method was used for this work.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

The Corrosion of Steel and Various Alloys by High-temperature Steam. (*H. L. Solberg and others, J. Am. Soc. Nav. Engs., Vol. 53, No. 4, November, 1941, p. 705.*)

(1) The resistance of alloy steels to high-temperature steam is greatly influenced by the amount of chromium present. Alloy steels containing 7% or more of chromium are very resistant to corrosion produced by steam at temperatures up to at least 1,400°F. The 18-8 stainless steels showed practically no corrosion when subjected to steam at temperatures up to 1,400°F.

(2) The corrosion rate is very rapid during the first 500 hours of testing, and then gradually diminishes as the time of exposure to the steam continues.

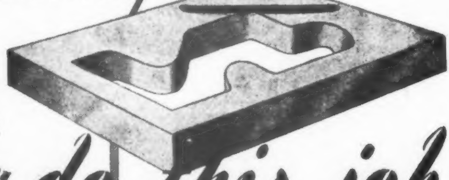
(3) Steam temperatures greatly influence the corrosion of steels. Except for steels containing 7% or more of chromium, the corrosion rate increases very rapidly at temperatures in excess of 1,100°F.

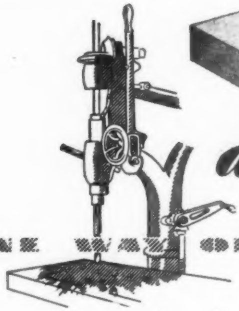
(4) The steels tested may be grouped into three general classes according to the type of scale formed. The first group consists of low carbon steel, carbon-moly, and the low chromium steels which are covered with a thick, porous, tightly adhering scale. The scale which forms on the steels of the second group, that is the 4-6 Cr steels and the 2 Cr-Moly-Al-Si steel, is very brittle and easily flakes off under fluctuating temperatures. The third group consists of steels having a chromium content of 7% or more, upon which a very thin, non-porous, tightly adhering scale is formed.

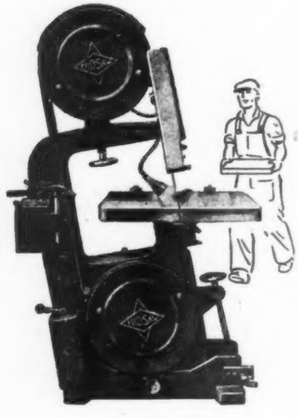
(5) Scale formed on the inner surface of a tube does not flake off as readily as the scale formed on the outer surface of a tube.

(6) Steam pressures between 100 and 1,200 psi gauge have no influence on the corrosion of steels.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)



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MEASURING METHODS, APPARATUS.

Standardised Controls. (*Aircraft Production, February, 1942, Vol. IV, No. 40, p. 192, 8 figs.*)

Standardisation, as a contributory factor to simplified construction, is still much to be desired in the modern airframe, and all possible methods of furthering its application are worthy of careful consideration. Flying control systems present a typical case for such standardisation. In this country a system has been introduced recently for application to main flying controls in which the problems of standardisation and interchangeability have been given special consideration. With the long control runs necessary in large modern machines it might be thought that torsional deflection of the tube would result in too much flexibility when the rotary movement was being used, and give a springy control. This possibility has been overcome by fitting a gear box with a 2 to 1 reduction at the cockpit end of the control run, so that the applied load is halved when transmitted through the tubes.

Pressure Gauges, by A. Linford. (*Machinery Lloyd, January 10, 1942, Vol. XIV, No. 1, p. 35, 13 figs.*)

Four principal types of measuring elements are used in pressure gauges which are operated by the deflection of the element caused by pressure variations. These may be broadly classified into the Aneroid barometer, the Schaffer or diaphragm, the Bourdon tube, and the liquid sealed bell types. Aneroid diaphragm type pressure recorder with roll chart (makers: Sigma Instrument Co.). Differential pressure gauge by Negretti & Zambra. Schaffer type diaphragm gauge (Budenberg Gauge Co.). Detail of Bourdon tube and movement (Dewrance & Co.). Coiled Bourdon tube type gauge (Bristol's Instrument Co.). Bell type pressure or vacuum recorder (Sigma Instrument Co.). Draught gauge for pressure (Dewrance & Co.). Edgewise type draught gauge (Negretti and Zambra). Indicating pressure gauge with electrical contacts (Budenberg Gauge Co.). Double-face indicating pressure gauge (Dewrance & Co.). Diagrammatic arrangement of air reaction type pressure recording installation (G. Kent, Ltd., Luton).

Small-part Rapid Dynamic Balancing Machine. (*Engineering, January 9, 1942, Vol. 153, No. 3965, p. 25, 3 figs.*)

The machine to be described is known as the Avery-Schenck No. 3001/A00. This machine is suitable for dealing with rotors, armatures, and similar small parts which run at high speeds and require careful balancing, the limits of capacity being 3¼oz. to 10lb. The machine is driven by 0·1 h.p. universal motor wound for use on a 230 volt, 50 cycle, single-phase supply, although other motors can, of course, be fitted. The disturbing centrifugal force due to unbalance in the work is ascertained by counterbalancing it with the centrifugal force of an "unbalance" weight of known magnitude and position. No special concrete foundation is required, a strong bench or table being all that is necessary, though, naturally, care should be taken that the machine is not affected by vibrations from adjacent machinery.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

MECHANICS, MATHEMATICS.

The Behaviour of Materials of Structural Elements under Static and Dynamic Load. (*B. Haas, Luftwissen, Germany, Vol. 8, No. 11, November, 1941, p. 338.*)

After discussing the behaviour of various ductile and brittle materials under single and multiple tensile stresses the author deals with the complications arising if the stress is periodic (fatigue) or sudden (impact).

In connection with fatigue both the Wohler and so-called "Damage" curves are discussed. The letter (German Schadenslinie) gives the overload which the material will stand for a given number of cycles without affecting its ultimate fatigue limit. It is interesting to note that certain kinds of surface treatment such as cadmium plating or heavy chromium deposits seriously reduce the fatigue strength of the parent metal, whilst phosphate layers or synthetic lacquers (stored) produce no deleterious effects.

Considerable space is given to a discussion on notch sensitivity and inherent stress distribution. The latter can be controlled by thermal (e.g. case-hardening) or mechanical means (rolling or shot blasting). In each case the size of the structural element plays an important part, and this shows the importance of carrying out tests on samples approximating to practical dimensions.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

PLASTIC MATERIAL.

Shear Strength of Moulded Plastic Materials. (*J. Delmonte, British Plastics, Vol. 13, No. 149, October, 1941, p. 134.*)

The punch and die are described in the measurement of shear strength upon moulded plastic parts as a useful tool for a rapid method of evaluating this property by moulders. Test results upon phenolics and ureas which have been cured for different periods of time are described. It is pointed out that differences in shear values of moulded phenolics are augmented by several minutes immersion in acetone, whereas boiling water may be used to reveal substantial variation in the cure of moulded urea parts and their shear strength. Comparative tests upon a large number of injection-moulded pieces produced in the same mould are outlined, and a table prepared comparing these materials with respect to shear strength. Injection mouldings of polyvinyl chloride-acetate and polymethyl methacrylate proved to be the highest. Further tests designed to show the utility of the punch and die reveal data on the sheer strength of moulded plastics as function of temperatures from 0° to 300°F.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

SMALL TOOLS.

Damage to Tools Caused by Faulty Grinding, by A. J. Schroeder. (*Machinery, January 8, 1942, Vol. 59, No. 1526, p. 426, 2 figs.*)

The finer the working surfaces are made with a view to the development of the minimum of grinding heat, the greater the durability and life. The most detrimental of faults produced in tool grinding are grinding cracks, burnt spots, reduction in the hardness of the edges, chatter marks, grinding tears and scratches. During grinding very high temperatures, 1,500°C. and over, are present on the surfaces of contact between the grinding wheel and work. In correct grinding it is only the chips, while being ground off, that become heated to such temperatures, whereas during incorrect grinding the part of the work touching the grinding wheel may also assume such inadmissably high temperatures. The most frequent causes of grinding cracks are the use of too hard a grinding wheel and grinding with too much pressure, i.e., with too large a feed. Further causes are a grinding wheel which is not correctly balanced, is clogged, is not dressed in due time, or is supplied with insufficient or intermittent quantities of coolant; or again, when the work ground has not been sufficiently cleaned. Burnt spots are of yellow, brown, or blue tempering colours, and appear on ground surfaces as a result of overheating of the steel. The grinding wheel actually burns the steel. Burnt spots result from the same grinding faults as grinding cracks.


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Chatter marks, tears, and grinding scratches impair the efficiency of cutting edges. Therefore every tool should be ground as smooth as possible. Grinding scratches arise through grinding with a wheel possessing too coarse a grain, and through too large a feed, or the too rapid movement of the work along the grinding wheel.

Care Makes Tools Live Longer, by C. H. Borneman. (*The Machinist, January 10, 1942, Vol. 85, No. 42, p. 953, 2 figs.*)

A tool used correctly will do the work of two or three tools improperly ground or misapplied. Tool breakage is the most paralysing factor affecting machine output. To conserve cutting tool materials, inserted tools and tipped tools should be used whenever practical. The possibility of obtaining satisfactory tools by salvage of existing tools should not be overlooked. Proper support of both cutting tool and work will conserve tools by increasing productive life. Minimum overhang, sturdy tool-posts, and well-supported milling arbors are all important factors. Proper alignment and location of tools with work will reduce wear and breakage. If holes are to be drilled and tapped on a radial drill each hole should be tapped immediately after drilling. Taps should not be overworked. For tough materials and deep holes tap drill sizes should be increased above the normal size. Only a half, a third, or even a smaller fraction of the life of a cutting tool will be obtained if the proper coolant or lubricant is not used. Taps are probably the most abused of all the cutting tools. A limited number of holes between resharpenings will add appreciably to tap life. In resharpening cutting tools the least possible amount of material should be removed from the cutting edges. Inspection of resharpened tools is specially necessary in the case of milling cutters.

Adjustment and Measurement of Tool Tips—III, by P. Grodzinski. (*The Machinist, January 24, 1942, Vol. 85, No. 44, p. 328E, 11 figs.*)

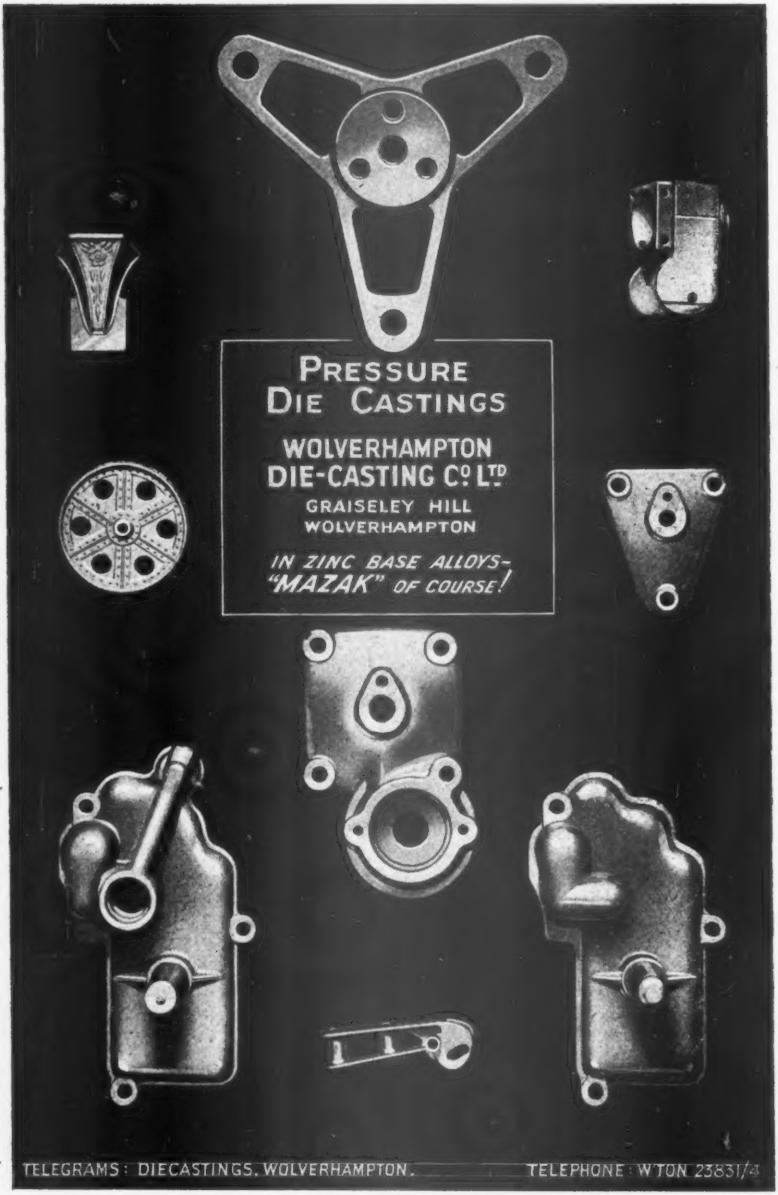
In many instances when several tools are cutting simultaneously, in particular on multi-tool lathes and automatic lathes, as well as in special machines and auxiliary appliances, it is not always possible to adjust the tool edge to the centre height or even approximately near to it. To exclude the dangerous adjustment below centre the so-called radial adjustment has to be used. This is on principle the basic adjustment of the tool edge towards the workpiece in order to obtain a proper cutting action, and height adjustment is only a special case of it. To adjust ordinary tools with rectangular shanks radially a wedge-shaped packing piece is recommended. Recently several tool holders have been introduced, particularly for investigation purposes, in which the actual tool shank is placed in a cylinder which can be rotated on a horizontal axis; thus any radial adjustment is possible. Very sensitive side adjustment is not possible by moving the holder in the tool post, as the subsequent clamping invariably causes slight alterations. Therefore tool holders have been suggested which permit over a larger range side adjustment of the tool edge.

Landis Collapsible Taps. (*Machine-Tool Review, September-December, 1941, Vol. 29, No. 179, p. 103, 5 figs.*)

Collapsible tap: (1) for parallel threads; (2) for taper threads.
Sectional view of details of the Landis tap.

A New British Boring Tool. (*Industrial Diamond Review, February, 1942, Vol. II, No. 15, p. 8, 1 fig.*)

A new boring tool with micrometric adjustment is described in Brit. Patent No. 539,539; Van Moppes. The boring bar is provided with a cross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hole for the reception of the tool shank, being of cylindrical form, but flattened on its upper side. The insert supports a micrometer spindle fixed in position by a grub screw.

Diamond Dies for the High-speed Drawing of Copper Wire, by H. N. Padowicz. (*Wire and Wire Production, October, 1941, Vol. 16, No. 10, pages 617 and 622.*)

Description of practice of the Western Electric Co. (U.S.A.) which draws Cu wire at 10,000-12,000ft. per minute. Die contour, inspection methods, recutting practice, die life and the mechanism of the ultimate failure of diamond dies are discussed.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

SURFACE, SURFACE TREATMENT.

Surface Finishing by the Spray Gun. (*Machinery Lloyd, January 24, 1942, Vol. XIV, No. 2 p. 46, 7 figs.*)

Spray guns are now employed for depositing polishes, bitumastic solutions, distempers, bronzing and frosting solutions, enamels, dopes, lacquers, varnishes—in fact, practically all materials which in the past were applied by hand. Victory model spray gun for suction or pressure-feed gun cap, overhead gravity, or pressure feed tank. "Ultra-Fanex" spray gun. Circular spray gun for spraying the inside of tubes, ingot moulds, &c. Flock spraying gun. Air compressors.

Chrome Hardening of Cylinder Liners. (*H. Van der Horst, S.A.E.J., U.S.A., Vol. 49, No. 6, December, 1941, p. 38.*)

Many experiments and many installations—well over 100,000 engines, chiefly Diesel—show that chrome plating of cylinder bores is an excellent remedy for wear. Not only is cylinder wear decreased by chrome plating, but wear of cast-iron piston rings is decreased to about one-fourth when running in chrome barrels.

Concerning the application of chromium to cylinder liners, the following must be noted: The electrolytic coating must adhere perfectly; the thickness of the coating must, within limits, be equal all around and from top to bottom; there must be no tiny ridges for the piston or the rings to run against; the ordinary bright, dense coating of chromium is not suitable as it does not hold lubricating oil, and in order to hold oil it is essential that the chromium be very porous.

The difference between ordinary chromium plating and the kind required for cylinder liners is most marked. The technique is of extreme importance, and is generally covered by patents.

(*Communicated by D.S.R., Ministry of Aircraft Production.*)

Hard Chromium-plating of Aluminium and its Alloys, by K. Gebauer. (*Korrosion, u. Metallschutz, August, 1941, Vol. 17, No. 8, p. 276.*)

A detailed survey, including a number of patented processes. Such plating is useful for highly stressed running surfaces, where resistance to wear, heat, and corrosion are required. It is suggested that "Al" hard-plated with "Cr" can be used instead of steel in all applications in which the strength of "Al" or its alloys is sufficient, and in which hitherto the wear-resistance of the "Al" surface has been insufficient.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

The Metal Coating of Plastics. (*British Plastics, September, 1941, Vol. 13, No. 148, p. 106.*)

A process has been developed by which very fine Zn, Al, Cu, or Sn dust is applied to give a smooth, adherent surface. This brief account deals mainly with the electro-magnetic screening properties of the Zn film, which are claimed to be good.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

TRANSPORT, TRANSPORT EQUIPMENT.

Shop Transport. (*Aircraft Production, February, 1942, Vol. IV, No. 40, p. 172, 10 figs.*)

Much time and research are done in the form of tool design. Quite frequently, however, the importance of inter-machine and inter-departmental transport of work is overlooked. Actually, considerable scope exists for thoughtful design in this field. Transport equipment of this kind should always be designed with a view to affording protection for the work and avoiding unnecessary handling. With a major component, such as a master connecting rod or an airscrew hub-casing, where as many as 100 operations may be necessary, the number of components and boxes handled, taking into account repeated loadings, is very large. A summarised comparison between box transport and the trolley system is given.

WELDING, BRAZING, SOLDERING.

Arc Welding of Cast Iron. (*The Welding Industry, January, 1942, Vol. IX, No. 12, p. 292.*)

Characteristics of cast irons. Silicon, phosphorus, sulphur, manganese, chromium, and nickel. Typical analysis of grey cast iron. Mechanical properties. Special cast irons. Nitrogen-hardened cast iron. Factors controlling welding procedure. Malleable cast iron. Characteristics of monel metal and its deposits on cast iron. The use of A.C. and D.C. circuits. Welding procedure.

Reactions of Non-ferrous Metals in Fusion Welding Operations, by W. Andrews. (*The Welding Industry, January, 1942, Vol. IX, No. 12, p. 281.*)

Varying reactions of the fusion processes. Carburising when excess of acetylene is used, oxidising with excess of oxygen or almost completely neutral according to the manner in which the proportions of the two constituent gases are adjusted. The atomic hydrogen flame is highly reducing in character. The presence of oxygen in tough pitch copper is desirable from the manufacturing point of view. Use of special filler rod. Necessity of a satisfactory flux. Alloys of copper. Bronze and brass. Straight tin bronzes.

WELFARE, SAFETY, ACCIDENTS.

The Industrial Front in Germany, by T. Prager and M. J. Wilkinson. (*Labour Management, January, 1942, Vol. XXIV, No. 256, p. 10.*)

A review of working conditions and social welfare in Germany since the war. Labour conscription. Reservation and technical training. Wage policy. Hours. Holidays. Food. Health: (1) accidents; (2) ventilation and lighting; (3) medical research and industrial psychology; (4) various other health problems. Travelling. Women in industry: (*a*) the care of young children by the State; (*b*) shopping, laundrying, mending; (*c*) selection of occupations for women workers and general problems of efficiency; (*d*) factory welfare officers; (*e*) wages of women workers. A considerable degree of foresight was exercised, not only with regard to technical training, but in questions like food rationing, research in industrial psychology, and the whole problem of female labour in industry. Dictatorial methods of compulsion played an important part in their achievement; methods which would not only be undesirable, but impossible in this country.

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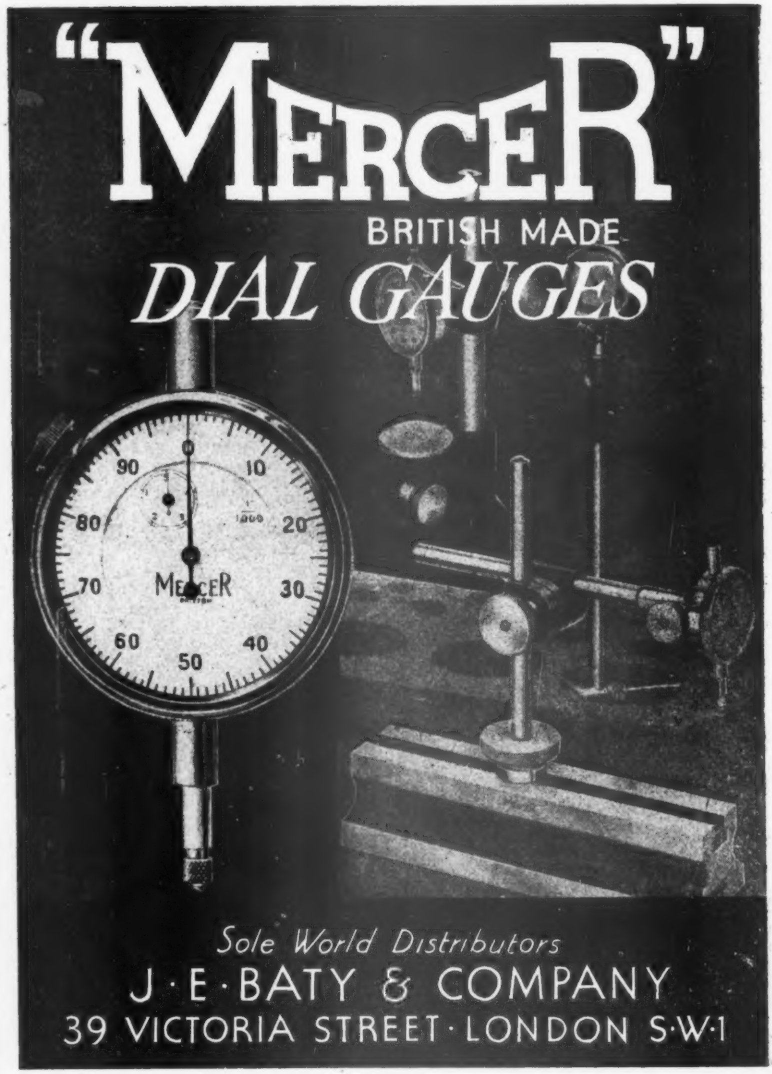
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